JAN 1 8 1946

MACHINE DESIGN

January 1946

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Government in Research

Design of Radar

No-We Didn't Put Sun Helmets and Swim Suits on our Motors-but....

"Double Trouble", moaned the experts, but the Navy stood fast. "All we want", said they, "are starting motors for diesel engines that'll stand up in tropic heat. Make them waterproof too!"

Blood pressures went up, when we ran into short-circuits. Horsepower had to be high (14-22 hp) and frames extra small (1/5 standard size). To offset this, operating periods would never last more than 45 seconds.

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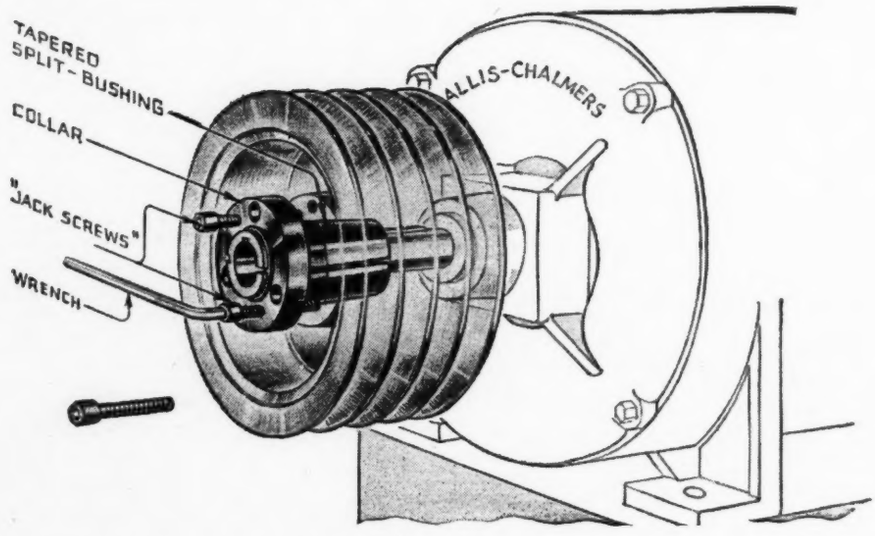

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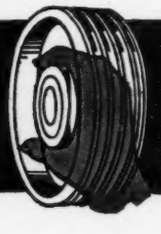

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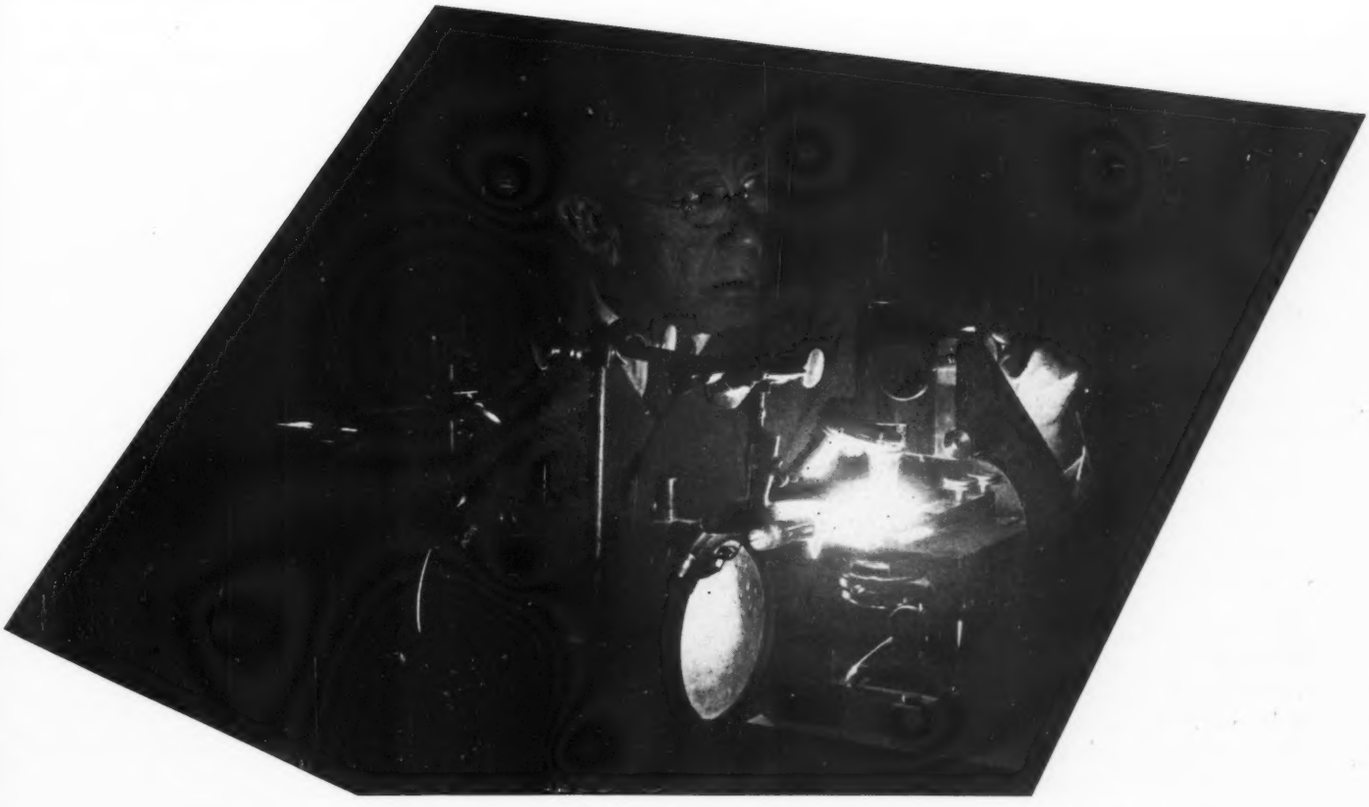


Government in Research?

By L. A. Hawkins
Formerly Executive Director
General Electric Research Laboratories

EVENTS of the greatest of all wars, now happily ended, have demonstrated in a spectacular and most convincing way the tremendous power of organized science backed by adequate resources. Not only our leaders in all fields—political, military, industrial, and educational—but also the general public are fully awake to the magnitude of this power, and the earnest intention prevails to develop and apply our nation's scientific resources with the fullest effectiveness for the common good. The danger is that that intention may be frustrated by faultv planning, as the result of inadequate understanding of essential factors, of emotional thinking or of bias by misleading preconceptions. It is to those two points—the sincerity of the intention and the misconceptions which may frustrate it—that I wish to direct my remarks.

In a report entitled "Science, the Endless Frontier," Dr. Vannevar Bush sets forth a recommended program for postwar research which is comprehensive, logical, and firmly

From an address delivered at the recent annual meeting of the American Society of Mechanical Engineers in New York.

based on his unrivaled experience as administrator of the greatest research undertaking the world has ever known. His recommendations have been embodied, I believe adequately, in a bill introduced into the Senate by Senator Magnusson and now under consideration by the Military and Commerce Committee of the Senate along with four other bills. Of the five bills, the two most comprehensive are that of Senator Magnusson, already mentioned, and one introduced by Senator Kilgore.

Magnusson and Kilgore Bills Compared

Although these two profess the same objectives and have many similarities, I believe the Magnusson bill is much to be preferred. It provides for a Research Foundation headed by a board of nine members appointed by the President solely on the basis of demonstrated capacity. The board is empowered to elect a director and to organize divisions to promote research in the fields of medicine, basic science, and military security, two members of the divisional committee for the latter field being appointed by the Secretaries of War and of the Navy. Thus the control is placed in the hands of scientists of proved ability, and the very necessary liaison with governmental departments is established at the divisional level. This is substantially the plan that worked so well in the huge war research program.

In contrast, the Kilgore bill sets up a board composed, half and half, of government officials and representatives of the public, with a director appointed by the President. The President also appoints the chairmen of the research divisions. This obviously offers more room for politics to creep in and is likely to result in a disturbing change of responsible personnel with every change in the White House.

As regards research in the medical and basic science fields, both bills properly contemplate that the work be done in universities and nonprofit research institutions. The only difference is that the Kilgore bill fixes the percentage of the total expenditure to be allocated to each field, while the Magnusson bill does not. Anyone who has had experience with research budgets and the varying fortunes of research projects knows how advantageous it is to have wide latitude in revising from time to time the allocation of funds.

Military Research by Industrial Laboratories

It is when we come to research in the military field, surely a matter of deep national concern pending the demonstration of the effectiveness of UNO in maintaining peace, that we find a most serious difference between the bills, a difference, in my opinion, between workability and inoperativeness. Military research is essentially applied research, the type of research found in all industrial research laboratories. It is work for which they are uniquely fitted by their close contact with engineering and production processes. It would be exceedingly costly to duplicate in governmental laboratories the facilities and specialized know-how already available in the more than 2000 industrial research laboratories of the nation. Both bills therefore contemplate the utilization of the know-how and facilities of these laboratories for a substantial part of the military research and development. But the Kilgore bill contains a provision which would make such utilization ordinarily impossible. It provides that all right to any invention made in the course of a research project, financed in whole or in part by the government, shall belong exclusively to the government.

Now let us see how that would work out in practice. Let us assume that the Army has in mind a new type of robot bomb, the success of which depends on the development of an alloy more resistant to high temperature than any yet available. And let us suppose that the Research Foundation turns to a manufacturer with a strong metallurgical laboratory which, over many years and with large research expenditures, has developed a number of successful high-temperature alloys which are covered by patents. Now no industrial company is anxious to divert any part of its research facilities to the projects of others. It is much more profitable to keep those facilities engaged on its own problems. But suppose from motives of patriotism the company accepts a contract and is highly successful, producing a better high-temperature alloy than any before. Now that company finds that it has no rights to that alloy. The government may license its competitors to make and use it, so its former patent position, obtained by years of work and expenditure of hundreds of thousands of dollars, has gone with the wind. Can government expect any company's patriotism to extend so far as to be willing to accept such a risk? Is it fair or reasonable to ask?

Patent Rights Question Left Open

Dr. Bush in his report truly says that ordinarily it should not be necessary for the government to insist on exclusive patent rights. Ordinarily, a royalty-free license for all governmental use should be adequate, so that commercial rights may be retained by the company. He therefore recommends that it be left to the judgment of the director of the Foundation to decide whether special circumstances warrant the government's demanding in certain cases more exclusive patent control than is given by a royalty-free license. Accordingly the Magnusson bill leaves open the question of patent rights.

I can conceive of any company's accepting, not eagerly but from patriotic motives, a research and development contract under the Magnusson bill, with a patent clause the same as was standardized by OSRD for war-research contracts. I cannot imagine any company accepting such a contract under the Kilgore bill. The patent provision in that bill in my opinion renders nugatory the entire portion which relates to the extremely important field of military research.

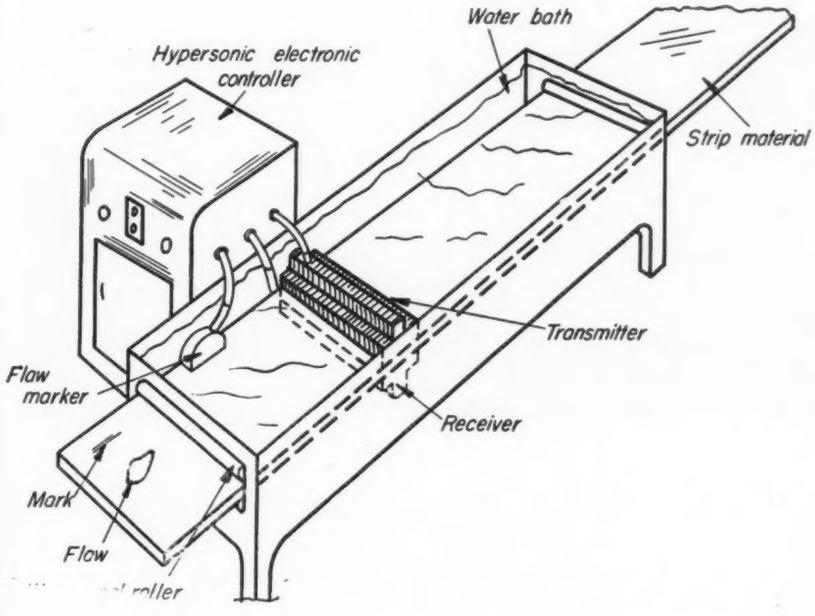
There is one exception to be noted. It evidently was the special case which Dr. Bush had in mind when he drafted his report, but which necessary secrecy at that time prevented him from identifying. It is the same exception which was made in the OSRD war contracts. In the project camouflaged by the name "Manhattan," the government demanded, and the participating industrial companies agreed, that all patent rights to all inventions relating to the process or to apparatus specially designed for the process should be assigned outright to the government.

This project was of course the one dealing with nuclear fission and the development of the atomic bomb. Industry recognized the special circumstances which made the government's requirement both necessary and reasonable.

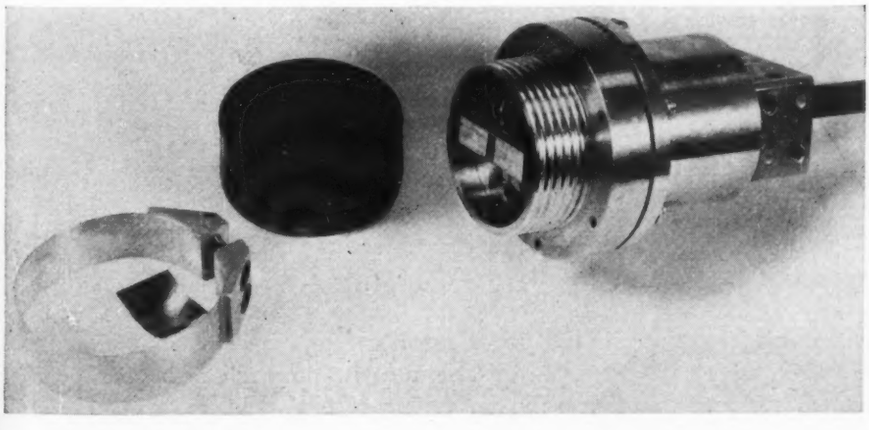
(*Concluded on Page* 180)

Scanning THE FIELD for Ideas

PRODUCTION testing of materials for flaws should employ fast, dependable and nondestructive methods. Such inspection, particularly for strip material, is facilitated by utilizing a method whereby a sound generator sends a high-frequency beam through the specimen. Depending on its properties, the specimen modifies the beam and the resulting energy pattern is picked up by a microphone on the side opposite the generator. In this way it is possible to select a critical set of radiation frequencies and electroacoustic designs so that the resultant beams through the material are highly modified by any given type of flaw in any given material. Since the frequency of operation normally lies in the region between 50 and 1000 kilocycles per second, material may be scanned at high speeds.



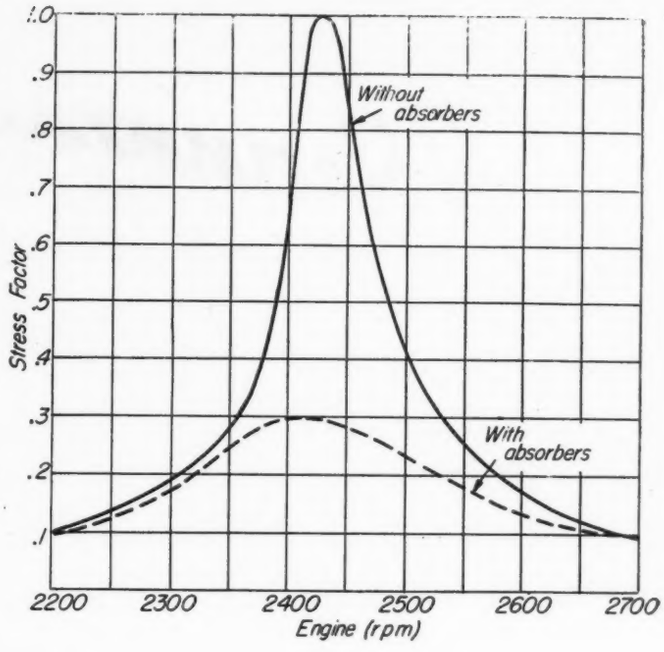
For use in this type of testing, a piezoelectric crystal unit, left, has been designed by the Brush Development Co. These units are used in their Hypersonic analyzer for both transmitter and receiver. A signaling or marking device, relay-actuated by the receiver, gives the necessary indication and location of flaws. In the sketch illustrated above is a series of transmitters and receivers applied to checking rolled strip stock. Water is used as the transmitting medium between the transmitter, material and receiver, the choice of medium being dependent on the material.



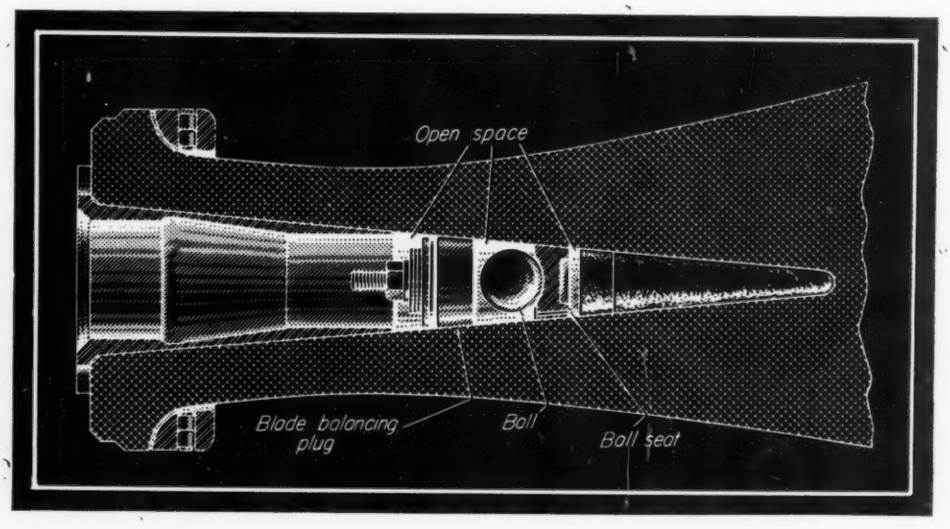
Flaws associated with two physical properties of the material are detected by this method —change in density and change in modulus of elasticity. The method does not distinguish

as to which property is changed but indicates that either one or both have changed. Because it is sensitive to changes in modulus of elasticity, thickness of slits or cracks as small as 0.001-inch are detected.

Tests have been made on many metals, all of which offer the same inspection possibilities. The method is also highly sensitive to flaws in plastics and other extruded materials as well as in bonding between laminations and materials.



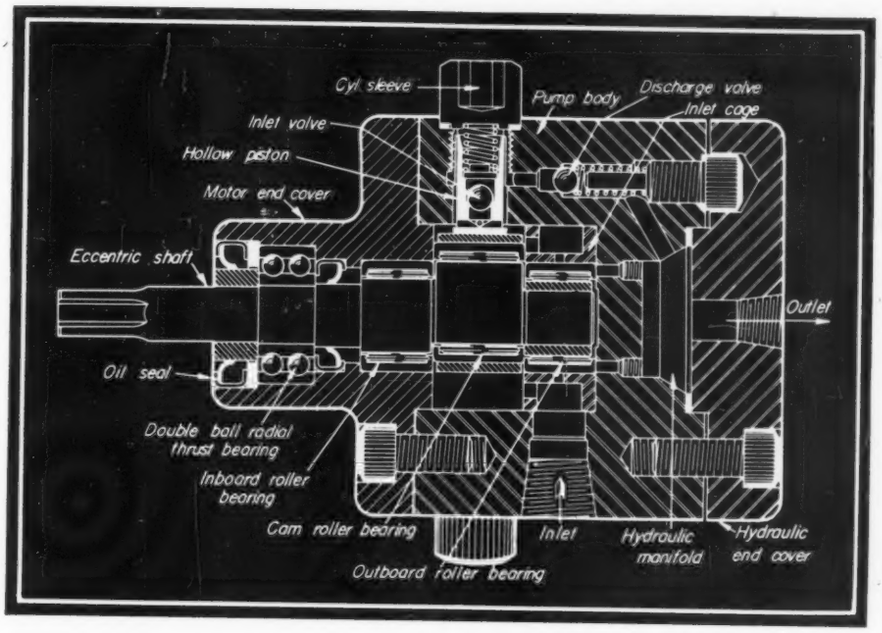
Vibration damper in the shank of propeller blade shown below utilizes the principle of vibration control in which excitations transmitted from the engine into the blade set up a rocking motion of a ball with a radius slightly smaller than that of the hollow in which it rests. This rocking motion varies in speed according to the frequency of the vibration and exerts pressure on the shoulders of the socket. These pressures are transmitted in turn by the seat to the sides of the blade, thus acting as a counter force to the torsional vibration to which the blade is subjected. Developed by Hamilton Standard Propellers division of United Aircraft Corp., the damper has increased the horsepower rating of the blades, reducing vibration stresses in the blade to less than half their former intensity. The curves above show how a torsional absorber reduces vibration stress by over two-thirds at the critical speed of the engine.



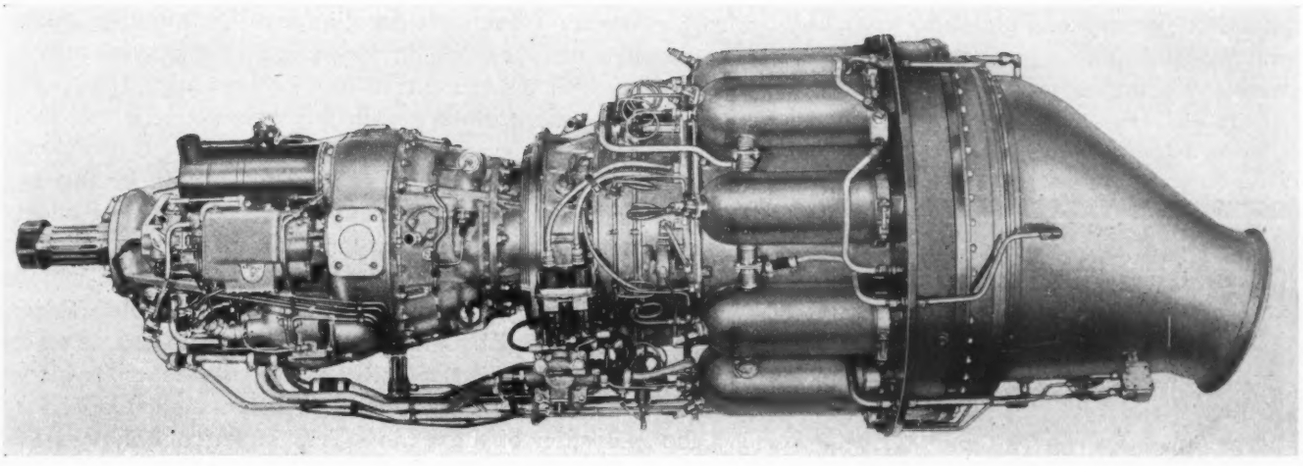
Hollow pistons function like leather cups to increase sealing properties as pressures build up in the radial piston pump shown in section at top of next page. Designed by Simplex Engineering Co., the pump develops pressures up to 1000 pounds per square inch, requiring that the fluid pressures contribute to the sealing properties of the mechanism. The hollow pistons are high-grade tool steel, heat treated to a hardness of 60 rockwell C to give high strength, elasticity and good wearing qualities.

As the fluid pressures build up inside the piston it expands and the sealing power is increased between the moving piston, cylinder wall and pump body. When the pressure is released, all surfaces return to their original dimensions. Because both the piston and cylinder sleeve are heat-treated steels with high elastic properties and the clearances around the piston and sleeve are a precise minimum, the deflection caused by the internal fluid pressures are well within the limits of these parts to expand with perfect elasticity and without permanent deformation. The higher the pressure, the tighter the seal between the moving piston, cylinder sleeve and pump body, obviating the use of soft packings.

Motion is transmitted by an eccentric shaft to seven piston and sleeve assemblies equally spaced radially. The flanged foot of the piston bears on a needle roller bearing floating on the eccentric cam. Consequently, the forces developed in moving the piston against the compressed oil are taken through the bearing with no appreciable slip on the piston foot. Valving of the oil to and from the pis-



tons is accomplished by hydraulically operated ball check valves. As with the hollow pistons, the fluid pressure is the major contributing force to prevent the passage of the fluid. The inlet valve is a free floating ball with limiting stops and its proper functioning utilizes the inertia forces generated by the piston in which it is located. Viscosity of the oil also contributes to prompt opening and closing. The discharge valve is similar except it is spring loaded to insure prompt closing. Sealing properties of the valves improve with operation.

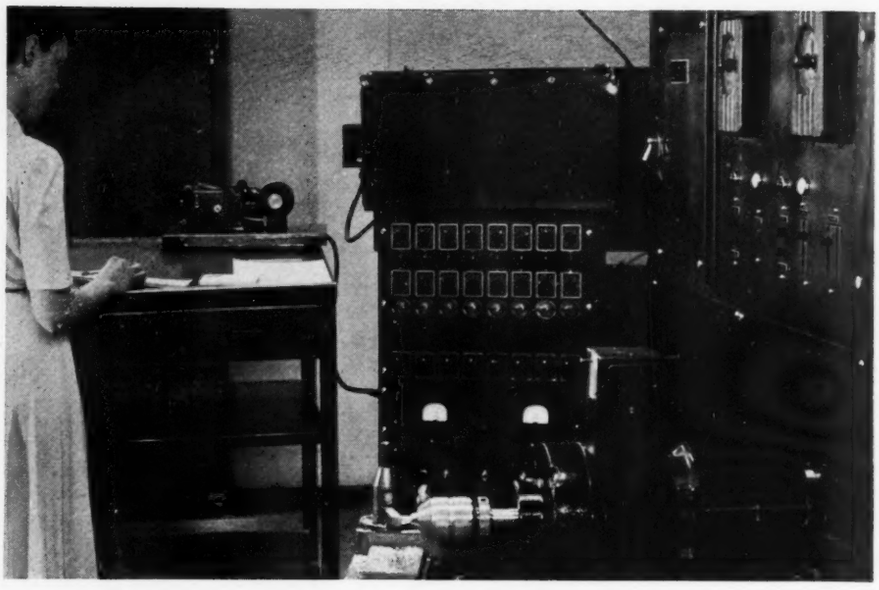


Two-way harnessed gas turbine drives through a propeller and boosts with jet thrust simultaneously. Shown above is a G-E Propjet, designed primarily to drive large high-speed military transports and bombers. It can be installed in the wings of multiengine aircraft or in the nose of single-engine planes. Air entering the nose through ducts is compressed by axial-flow units in the forward part of the engine and then forced into combustion chambers. There fuel is injected, raising the temperature and velocity of the gases. The major part of this energy is absorbed in driving the turbine and its propeller. The remainder is discharged rearward and is utilized as jet propulsion.

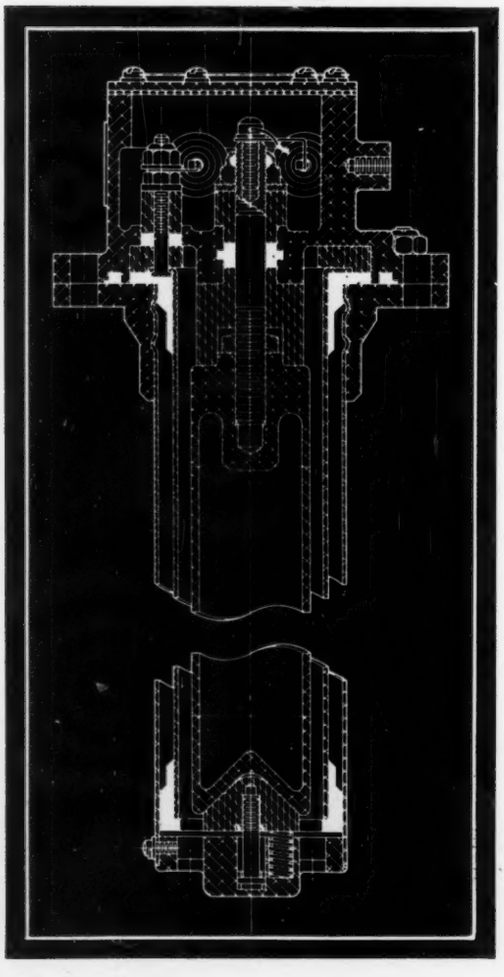
High power is generated by these units and engineers see no basic difficulty in increasing the propulsive output to almost any force required for future planes. Major advantages of this new design include: Lighter weight, simpler and more compact design, virtually no vibrations, continuous and economic operation at full power, and utilization of almost any liquid fuel. Although the extreme high speeds attainable with pure jet engines may not be reached in planes powered by this type of unit, cruising speeds about 500 miles per hour are attainable. Compressibility barriers reached by all propeller-driven planes limit speed near this value.

Electronic measurement of the concentration of elements in alloys is automatically recorded by a direct reading spectrometer. While taking but a fraction of the time required by a standard spectrometer, this unit can analyze an alloy in 40 seconds. Developed at the Dow Chemical Co., the instrument substitutes an electronic method of measur-

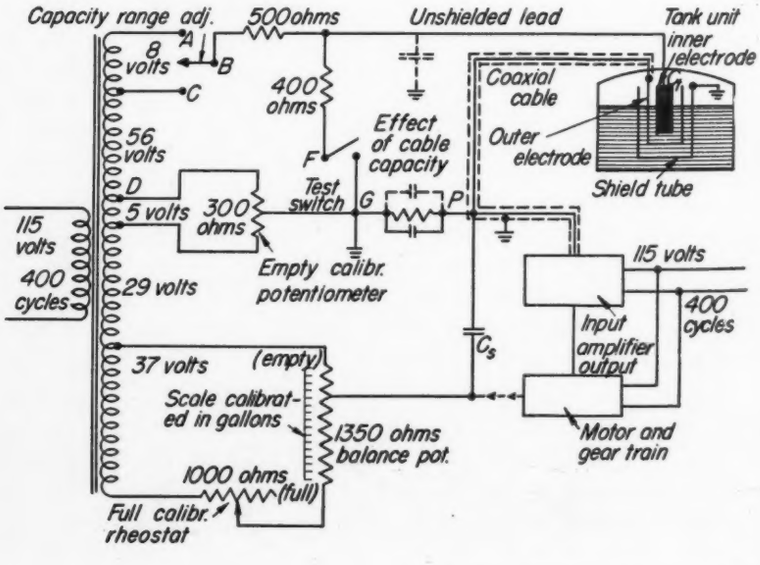
ing the intensity of spectrum lines, right, and eliminates the necessity for photographic and developing equipment and an expensive microphotometer. Also it avoids the errors commonly encountered due to film variation. Up to 14 elements can be determined simultaneously.



No movable sensing devices are needed in tank unit, below, for an electronic-type fuel gage. Instead of floats or other mechanical elements, the dielectric properties of gasoline are utilized to furnish a direct measurement of fuel quantity. Developed by the Aeronautical division of Minneapolis-Honeywell Regulator Co. for aircraft, the tank unit is composed of three concentric aluminum tubes. The outer tube is grounded and acts merely as an electrostatic and mechanical shield while the two inner tubes function as plates of a condenser. Change in gasoline level in the tubes varies the dielectric constant and thereby affects the capacitance in accordance with the amount of fuel in the tank. This capacitance varies more directly with the weight of the fuel than with the volume, giving an indication independent of volume change due to temperature variations, the reason for this being that increase in volume due to expansion inversely affects the dielectric constant over the temperature range of aircraft operation.



Simplified bridge circuit for this gage is illustrated below. The motor controlled by the circuit is geared to a pointer on the face of a fuel indicator unit. A test pushbutton is incorporated in the system to provide a convenient means for checking the operation of the gage. This button unbalances the circuit, causing the motor to drive the dial pointer. Upon release of the switch the indicator should return to normal position.



What's Behind Airborne Radar?

By Donald M. Skidmore and Charles R. Chambers
Sperry Gyroscope Company
Garden City, N. Y.

Part I—Electronic Units

AIRBORNE radar owes much of its success to various electronic components that prior to the war either did not exist or were in only a crude form of development. Without these components, pictures such as the views shown in *Fig.* 1 would not be possible on the screens of search and navigational radar sets. These pictures, which show the pilot what is on the surface of ground or water below him, exaggerate (as in *Fig.* 1) the size of ships, while large objects on the ground seem to blend into one bright mass.

Range finding by radar employs the old principle of sending out a pulse of electromagnetic energy and then measuring the time that lapses before echoes are received. This is a simple principle but since radio waves can travel and return a mile in about 10-millionths of a second, the time measuring system must be incredibly fast-acting when compared to ordinary machines or human reactions.

Cathode-ray tubes, because of their almost instantaneous action, lend themselves to the measuring of time down to fractions of microseconds. Both the tubes and the circuits which operate them have been improved greatly during the war because of the demand for better radar results. For example, one of the simplest radar range indicators consists of an electrostatic cathode-ray tube to which a saw-tooth shape voltage wave is applied to one set of deflection plates, while the transmitted pulse of the radar set and the return echo pulses are applied to the other set of deflection plates. The saw-tooth wave in this case is used to produce a horizontal sweep on the cathode-ray tube similar to sweep normally presented on an ordinary oscilloscope. This sweep is so timed that it starts on one side of the screen and moves to the other side each time the radar transmitter sends out a pulse. If this trace moves at the rate of 1 inch in 10 microseconds, it will have moved one inch when the echoes from an object one mile away are returning. Since these echo pulses are applied to the other pair of deflection plates, they put wiggles in the horizontal trace at a distance corresponding to their range from the radar set. In other words, in order to make objects a mile away appear one inch from the start of the range sweep, it is necessary to have the electronic beam in the cathode ray tube moving at 0.10-inch per microsecond, a speed in excess of 7,000 miles per hour.

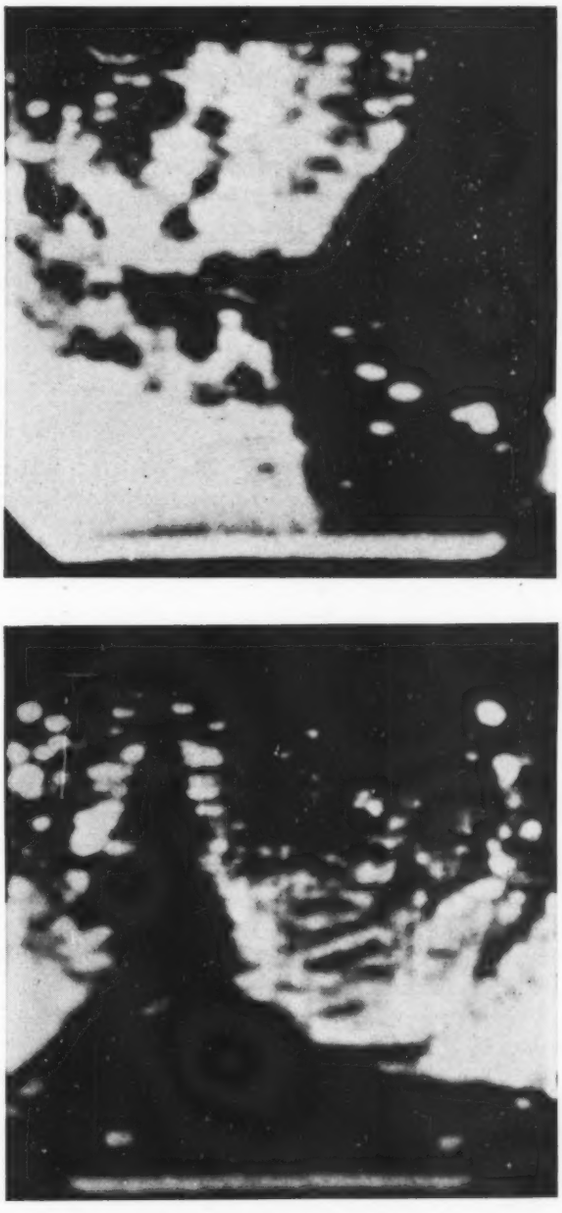


Fig. 1—Top—How New York Bay looks on the screen of a radar scope. Bottom—Picture of Long Island Sound. Dark portions in photographs are water

In prewar cathode-ray tubes, when the electron beam moved at such speeds, the trace became correspondingly weak. During the war, however, tube manufacturers developed screen coatings that would give a bright picture even at high sweep speeds. In addition to increasing brilliance, the persistence of the tubes was increased so that they would glow for many seconds after being illuminated. This persistence gives an integrating effect which allows

the radar picture to become brighter each time a frame is repeated.

In addition to the rapid modification of the cathode-ray tube, the receiver and video amplifier components that supply the signals to it were similarly modified to handle the extremely high frequencies and short pulses. In many cases the frequencies used are so high that vacuum tubes cannot be used to detect them efficiently. As a result many radar receivers use crystal detectors. The crystal detector set, dead as the dodo for many years, suddenly

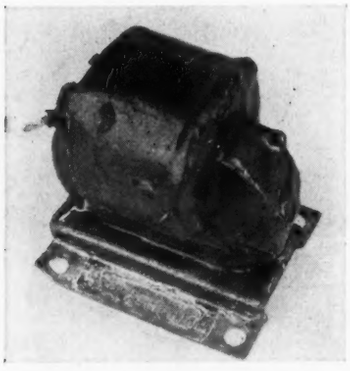


Fig. 2—This plastic coated choke coil is lighter than similar units that are "potted" or canned

came to life again because it promised to give quicker results than vacuum tube detectors at the new microwave frequencies. Over 10 million dollars were spent on the development and production of crystal detectors for airborne radar sets alone. The excellent crystals that were produced as a result of this effort, enabled us to operate on higher frequencies than the Germans and Japanese supposed were being used.

Use of new and higher frequencies, in addition to confusing the enemy, enabled us to employ smaller parabolic antennas. The smaller the wavelength is in proportion to the size of the reflector, the sharper the radio beam that can be obtained. It is important, in radar, to transmit and receive with a highly directional antenna so that accurate angular data may be obtained in locating a target.

Generation and reception of these microwave frequencies were made possible by the development of two new high frequency tubes; the magnetron and the Klystron. The magnetron is capable of putting out enormous amounts of microwave energy for short intervals. Consequently, it is used as the transmitter in most airborne sets where long range operation is one of the desired results. The Klystron is more suited to putting out microwaves continuously but at lower power levels. It, therefore, is usually employed as the oscillator in the radar receiver. Both the magnetron and the Klystron, when originally invented, were bulky objects weighing many pounds. But when tube manufacturers, backed by the Army and Navy, began to work on these tubes, they produced magnetrons and Klystrons at 1/10 of their original weight.

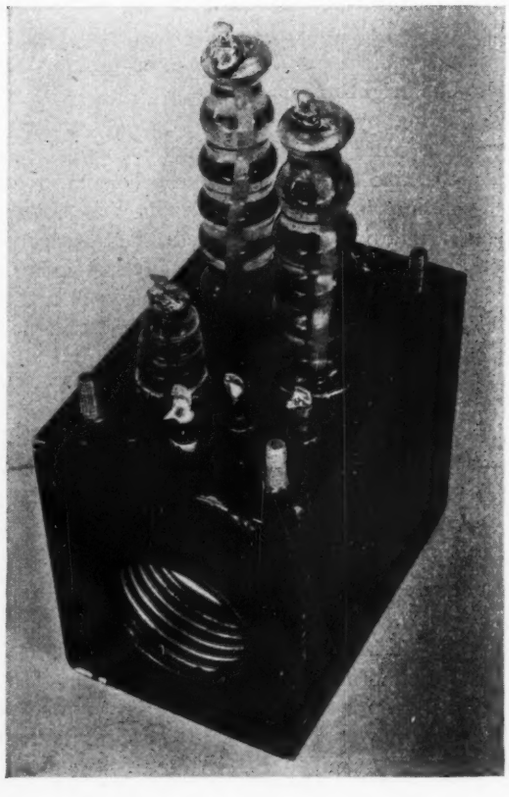
A change in the power supply frequency also helped to get radar into the air. Most airborne radars now operate on power supplies that range from 800 to 2,400 cycles per second. The heavy transformers, chokes, and condensers that are common in 60-cycle electronic equipment can be greatly reduced in weight and size for 800-cycle operation. A glance at the familiar formulas $Z = 2\pi fL$ and $1/2\pi fC$ will show that as f is increased, L and C may be decreased and the same result achieved. Consequently, much less iron is needed in cores and fewer condensers needed in filters.

Development of lightweight radio parts, although not as spectacular as the invention of the magnetron or Klystron, was equally important in making successful airborne radar. Most radio components before the war were designed to do the job as inexpensively as possible. Little attempt was made to produce light components, particularly if such an attempt would increase costs. Since the problem of reducing the weight of radio components had scarcely been touched before the war, the results achieved were appreciable. Curiously enough, while cutting down the weight, many of the components were simultaneously improved. Transformers and iron-core chokes, for example, are normally the heaviest parts in a radio. This is particularly true if they are the "potted" type in which the transformer unit is enclosed in a pitch-filled can.

How Industry Lightened Transformers

This problem of designing lighter transformers was attacked by the transformer industry from three angles. One method was to develop higher grade iron alloys that would give high magnetic flux density with less core cross section. A second approach was to increase the heat dissipation so that smaller copper wire could be used without excessive temperature rise. The third approach was to eliminate the need for "potting" or canning transformers by treating them with coats of plastic or resinous finish. Several of these baked finishes were successful not only in reducing weight but also in making the transformers more moisture and fungus-proof. In addition to being good sealing compounds, several of these coatings are good insulators with high dielectric strength. Allowed to flow into

Fig. 3—Sealed high-voltage transformer showing glass and metal units soldered together



the windings of a transformer, they protect against high-voltage break down. Many transformers that formerly were of the oil-filled type now are made much lighter by using one of these coatings instead of oil. A plastic-coated choke coil is shown in *Fig.* 2.

English engineers developed a lightweight method of sealing their high-voltage transformers which, although not used by this country, was inexpensive and effective. This method consisted of molding a form-fitting synthetic rubber bag around the transformer. The bag was then oil filled. Since it cleared the transformer by a fraction of an inch, very little oil was used and the weight was small. When the transformer heated, the molded rubber case simply expanded and no additional device was necessary to allow for oil expansion.

Development of lightweight tubes, condensers, and chassis actually started when the radio industry brought out portable radios. Consequently, most of the effort on these parts during the war was put into making the already light components more reliable and better able to withstand military requirements. This work consisted mainly in developing new manufacturing techniques in the fabrication and assembly of the components. For example, the technique of soldering metal to glass or porcelain was perfected to make air-tight and water-tight seals, *Fig.* 3, between terminal assemblies and metal cases. The use of these metal-to-glass joints permitted delicate electronic circuits to be totally housed in a pressurized can without danger of leakage around the terminals. First attempts to make metal-to-glass seals usually resulted in a joint that was likely to crack from vibration or thermal change. By using metals such as silver and kovar which expand and contract at substantially the same rate as glass, the cracking difficulty was overcome.

Sealing of components has not been restricted to small units. All the better airborne radars now are totally enclosed in pressurized cans. This feature allows the equipment to operate at 50,000 feet without danger of high voltage arc-over. The problem of pressurizing electronic equipment has demanded close collaboration of mechanical and electrical engineers because, as soon as a high-power radar unit is "canned", considerable thought has to be given to dissipating heat generated by the equipment.

Units now are being built in which 450 watts are dissipated inside a 1½ cubic foot sealed container. The temperature rise of such a unit is 22 degrees C above the ambient temperature at sea level. Such a container, *Fig.* 4, is actually a triple-walled can, the middle wall being air-tight. The hot air is circulated between the inner and middle walls by an internal blower, while cold outside air is circulated between the outer and middle walls by the external blower. The inner wall is made of magnetic shielding material to prevent the radar from deflecting the nearby instruments. A molded pressure-tight plug for making electrical connections into a pressurized transmitter is shown in *Fig.* 5.

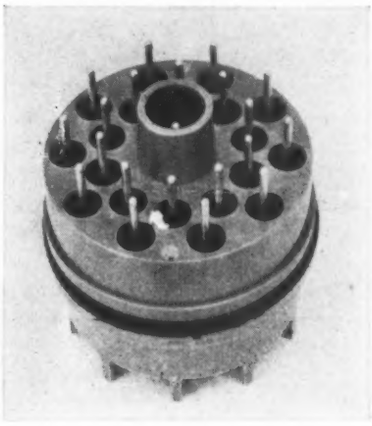


Fig. 5 — Molded pressure-tight plug for making electrical connections into a pressurized transmitter has long leakage paths between pins

The problem of sealing radar units started as an electrical necessity and soon grew into a full-time mechanical job. This overlapping of work is typical of the whole airborne radar production program. Some of the mechanical developments that have accompanied and supported the electronic work will be dealt with in Part II of this series.

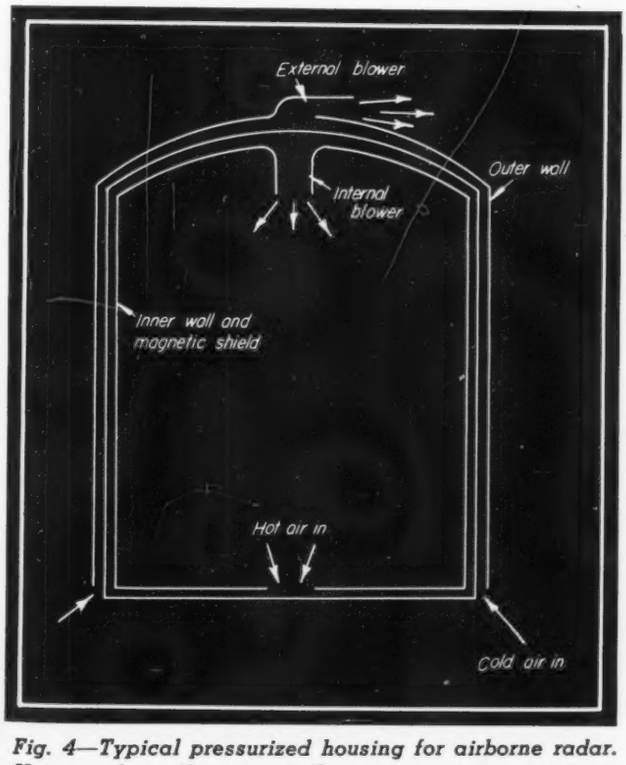


Fig. 4—Typical pressurized housing for airborne radar. Units such as this permit the equipment to operate at 50,000 feet without danger of high-voltage arc-over

Radar Countermeasures*

In the words of Dr. Vannevar Bush, "The new eyes which radar has supplied can sometimes be blinded by new scientific developments". Just as the chemical mask was perfected as an answer to poison gas, and the radar-controlled antiaircraft gun was arrayed against the buzz-bomb, so too have means been developed to counter the effectiveness of radar.

It will be remembered that radar works on the principle of echoes. Figuratively speaking it "shouts" or transmits a loud signal into space and then listens for the faint echo to return. Herein lies the first weakness of radar,

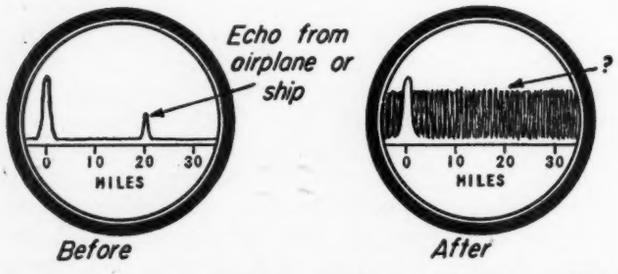
*From a report released by the Joint Board on Scientific Information Policy for the Office of Scientific Research and Development, the War Dept. and the Navy Dept.

for its strong transmitted pulses can be detected at distances greater than those at which it can detect objects.

Secondly, radar not only betrays its existence but its exact location as well. Once a radar signal has been tuned in on a radio receiver, it is possible by means of an attachment to the receiver to measure the bearing of the radar and thus determine its location.

A third weakness of radar is the fact that the returning "echo" signal is extremely weak. It is only necessary to equip the target with a device that sends out a radio signal capable of covering up the signals reflected back to the radar from the target. This process is known as electronic jamming. Because each radar set operates on a particular frequency channel, it is required that the "jammer"—which is fundamentally a small radio transmitter—be tuned to the same channel. Normally the reflected signal from a target appears as a vertical spike or "pip" on a radar's cathode-ray tube "scope". When the radar is being "jammed", however, the scope screen is cluttered with vertical spikes and the signal from the target is lost in the "grass" (see illustration).

The fourth weakness making up the Achilles' heel of radar is the fact that it cannot distinguish the nature



Radar scope screen before and after jamming. When jammed, the target-indicating pip is lost in the field of pips or "grass" transmitted by the target's jamming device

of small objects. To a radar, one small object looks about the same as another. For example, as viewed by radar, an airplane or a ship is a small object. It was found that a number of thin metallic strips cut to a length proportional to the wavelength used by a radar, return a remarkably strong echo to that equipment. Several thousands of these thin metallic strips, packaged in a bundle weighing less than two ounces, will give a radar echo signal equivalent to one bomber when the strips are ejected from a plane and allowed to fall freely through the air. The phenomenon is one of resonance, the metallic strips, designated by the code name "Window", being resonant at the frequency of the radio microwaves sent out by the radar.

Another countermeasure having the same effect as "Wndow" is known as "Rope". Our B-29's used Rope extensively in the Pacific theater, with telling effect. Instead of many short strips of foil, Rope consists of 400-foot aluminum foil ribbons suspended from parachutes. Particularly effective against Jap low-frequency radar, the protection provided by Rope was considered so important that ultimately nearly 600 pounds of the stuff was carried in all B-29's on every mission. In one case a Navy Catalina flying boat accompanied a group of low-flying mine-laying planes into Manila Bay on an operation considered certain suicide for all. The judicious use of jamming transmitters, coupled with the dropping of Rope, so confused the Jap radar defenses that many of the stations went off the air, guns were fired wildly, and the attacking U. S. planes were able to complete their mission without a scratch.

One of the most ingenious countermeasures developed during the war was a device known as "Tuba", a tremendously powerful jamming transmitter created specifically to blind German night fighters which used an airborne interception radar known as "Lichtenstein" for close-range location of their targets. Against them the British found it impractical to use jammers carried in their bombers, because the jammer itself provided a signal which the German fighters could use to locate the bomber. These fighters, however, did not usually reach their prey until after the British bombers were flying home from a mission. Someone suggested, why not set up a very high-powered jammer in England to blind the German fighters' radar as they flew toward it in pursuit of the homeward bound bombers?

A jammer of this sort required enormous power and this power problem was solved by means of a remarkable vacuum tube, developed in the United States, known as the "resnatron". It was necessary to build a resnatron that would be tunable over a wide frequency range, because the Germans could change the frequency of their radars by slight modifications. Also, a way had to be found to modulate the resnatron's output with the random "noise" necessary for jamming.

The power output of Tuba is of such unforeseen magnitude that our planning for frequency channel allocations in the ultra-high-frequency range will be affected directly. Tuba, by raising the sights on what is possible, has made existing thinking obsolete, and will tremendously advance the development of ultra-high-frequency broadcasting.

ASME Forms Machine Design Group

RECOGNIZING the ever-increasing importance of the field of design, the American Society of Mechanical Engineers has sponsored the formation of a Machine Design Group. Organized primarily for the presentation of technical papers of interest to machine designers generally, rather than to any specific branch of industry, the new Group may later assume the status of a full-fledged professional division should interest continue to increase among ASME members and others active in design.

Chairman of the Group is J. F. Downie Smith, head of the engineering department at United Shoe Machinery Corp's. Research division, the secretary being B. P. Graves, director of design, Brown & Sharpe Mfg. Co. Plans are under way for a machine design session at the semiannual meeting of the Society in Detroit next June, and consideration is being given to the scheduling of joint sessions with other professional divisions where desirable.

Meetings to be held under the auspices of the new Group should offer much of interest to designers in connection with the technical discussions as well as the opportunities to meet with other engineers having closely allied interests.

Air Controls Provide "Feel" in Operation

By W. M. Huston
Mechanical Engineer
Shovel and Crane Div.
Lima Locomotive Works Inc.

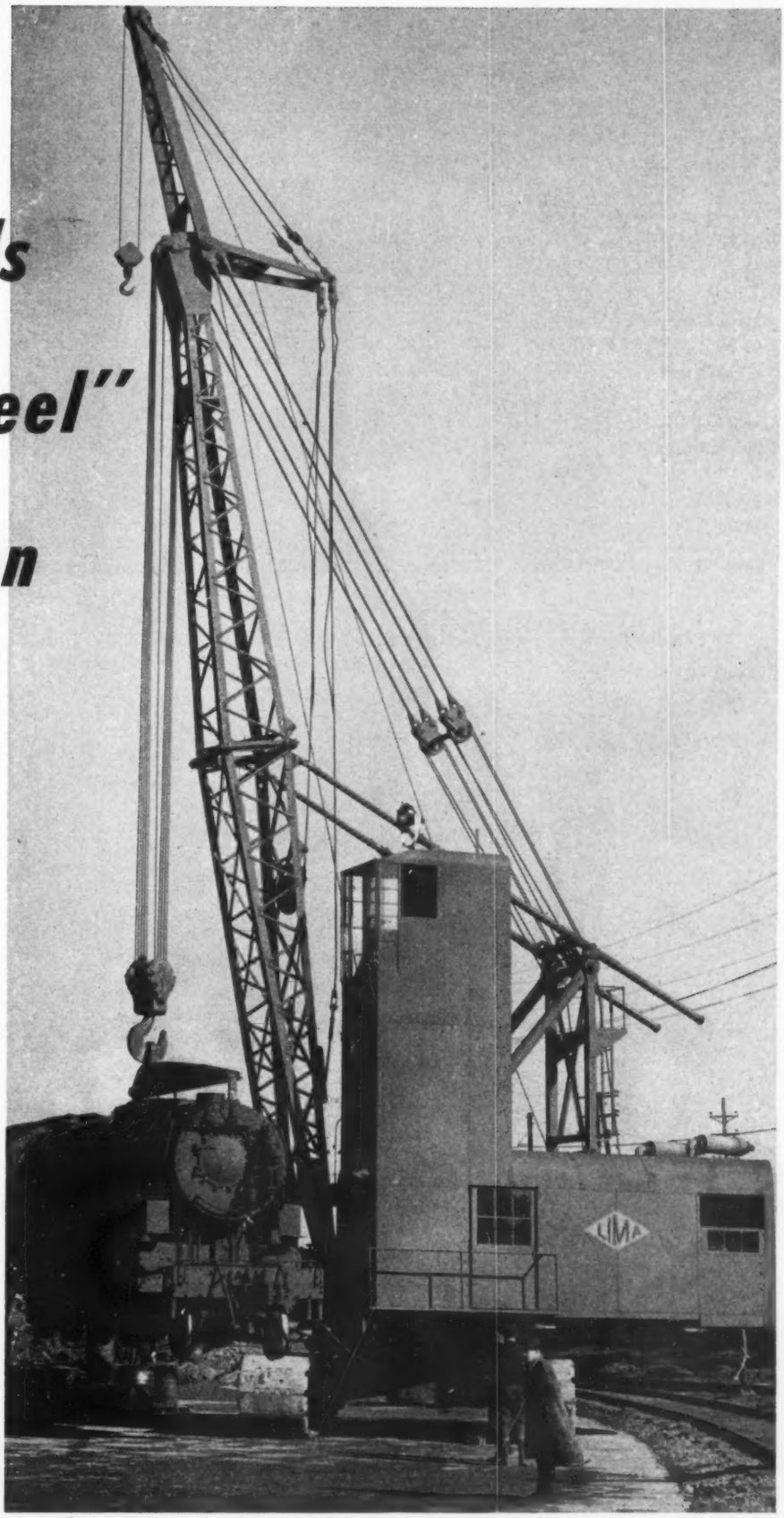


Fig. 1—One-hundred ton crane incorporates pneumatic controls for sensitive response and dependability. Control valves are graduated and compensating to give operator the feeling of direct response to lever movements. Quick-release valves located at the power cylinders obviate back pressure of discharge lines

FROM the standpoint of flexibility, dependability and "feel" of control, a direct manual control is ideal. As machines become larger a point is reached where the manual effort is too great and the operator suffers from fatigue after a certain length of time. Production naturally falls off, resulting in less profitable operation of the machine. Some means, therefore, of using the energy of the prime mover is generally utilized. Compressed air or hydraulic fluid are popular mediums for this purpose. In either case the medium is pumped to a storage reservoir at predetermined pressure from which distribution to the various operating valves is accomplished by means of tubing.

Capable of handling 100 tons at

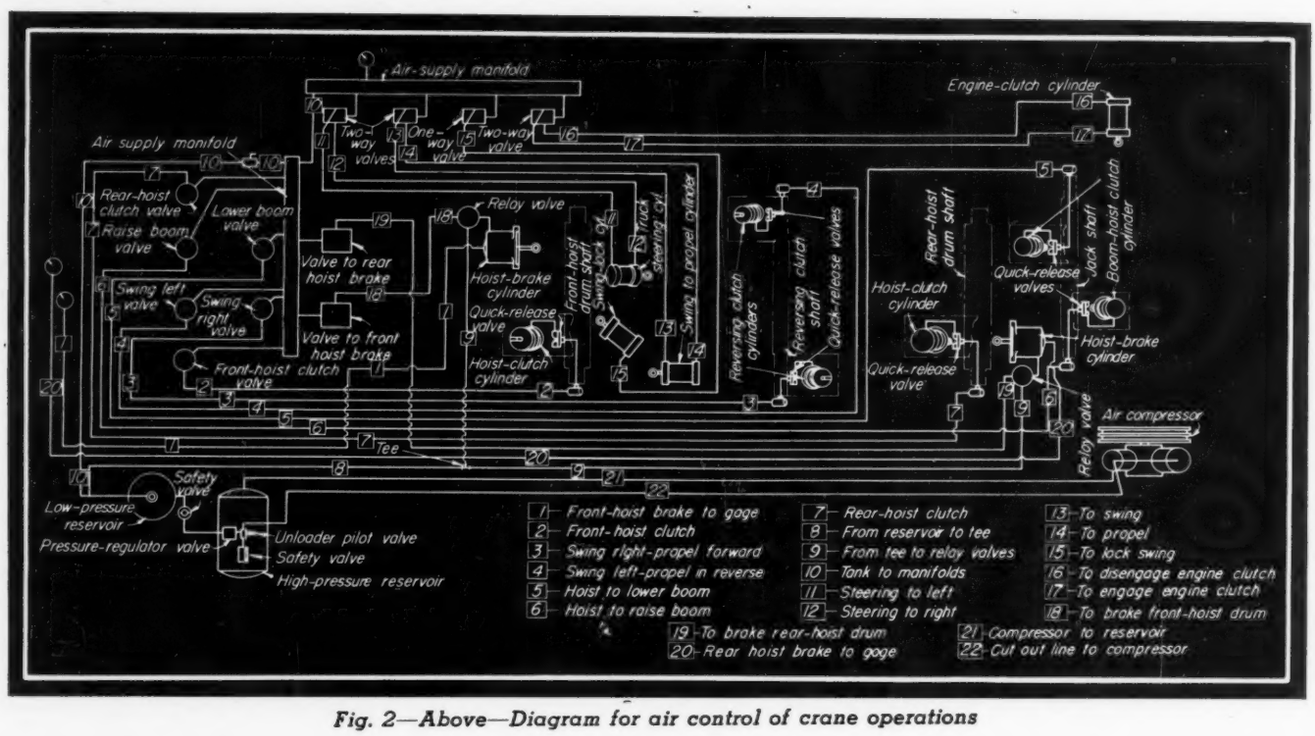


Fig. 2—Above—Diagram for air control of crane operations

Fig. 3—Below—Operator's compartment showing location of clutch controls and foot pedals for brakes. Center foot pedal is accelerator for engine throttle

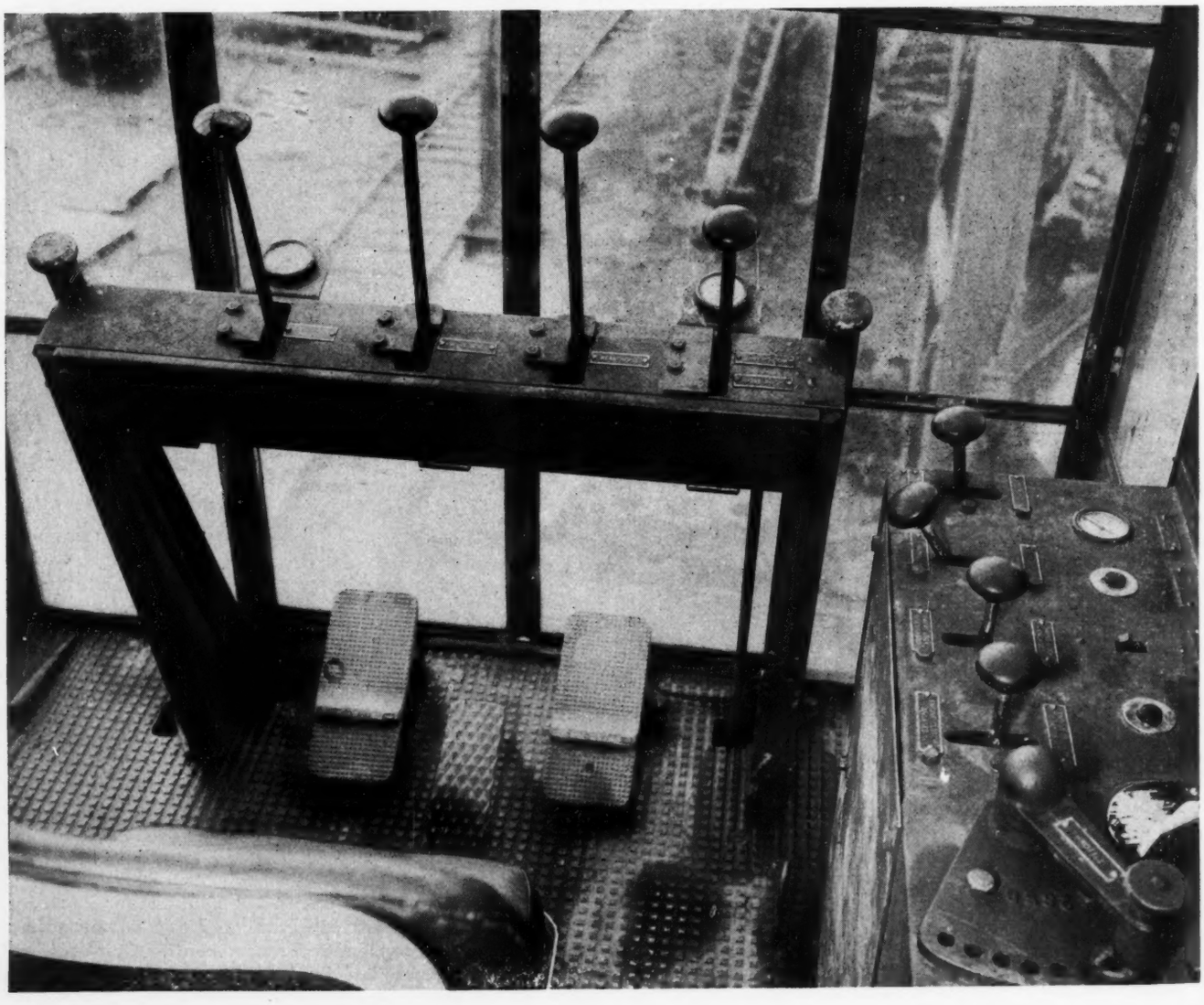
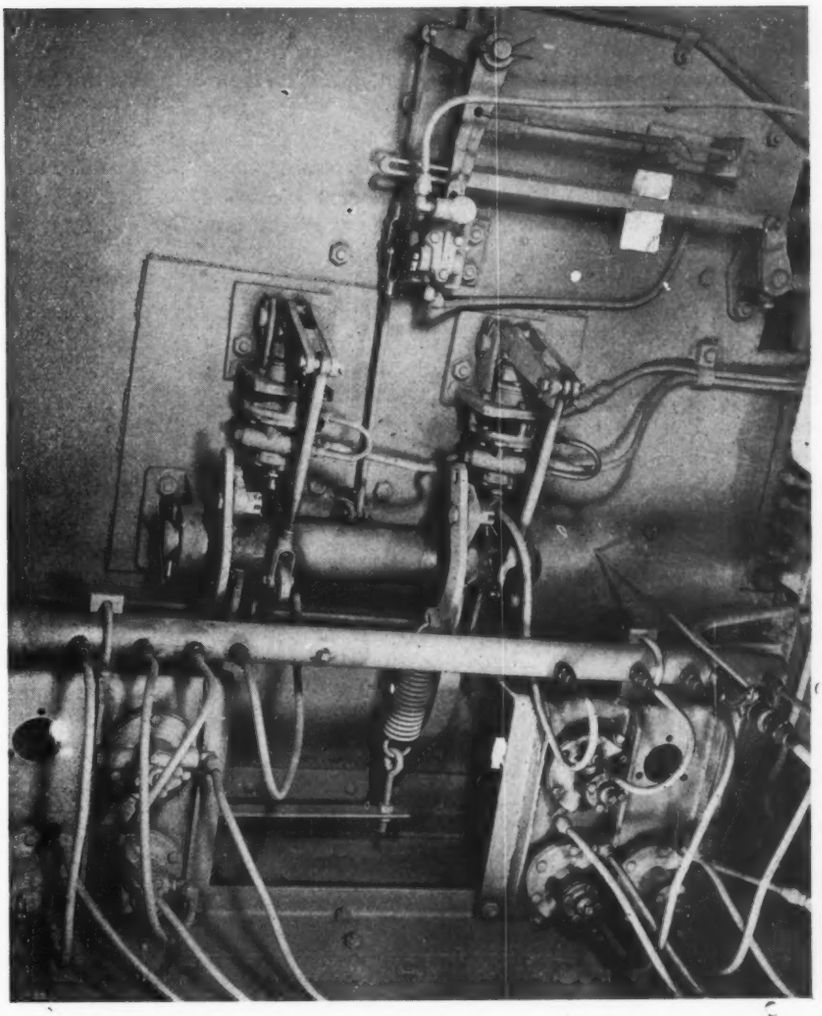


Fig. 4—Right—Arrangement of clutch air control valves and also foot brake air control valves. These valves are located beneath the floor plate of the operator's compartment



a 15-foot radius the crane shown in *Fig* 1 has air controls on all operating functions such as hoisting, swinging, boom raising and lowering, propelling, steering, cab lock, master engine clutch, hoist brakes, etc. On smaller machines these functions formerly were controlled manually or manually with some form of a mechanical booster.

Prime requisite of any system of power control as applied to this type of machinery is its ability to duplicate the performance, flexibility and dependability that generally exists in all types of manually controlled shovels and cranes. In any power-control system the selection of the proper type of control valve is of first importance. The valve selected or designed should be time tested, dependable, long lived, graduated, and compensating.

By graduated is meant the ability to admit and hold air or hydraulic pressure for each increment of movement of the control lever. By compensating is meant the ability to register reaction on the control lever for each increment of movement.

Meets Control Requirements

Air control was selected for the Lima crane because it best met the exacting requirements as outlined. Compressed air will function at comparatively low pressures; this feature is conducive to lower load on all contributing and operating parts such as air lines, control valves, air cylinders, etc. The end result being dependable operation over long periods of time, low costs of maintenance, and freedom from costly shut downs.

An air piping diagram as applied to this crane is shown in *Fig.* 2.

The air compressor shown at the lower right is driven by a V-belt from the engine crankshaft, not shown in this drawing. Compressed air is pumped through line 21 to a high-pressure reservoir. When the pressure reaches 150 pounds per square inch, an unloader pilot valve in the reservoir opens and admits air

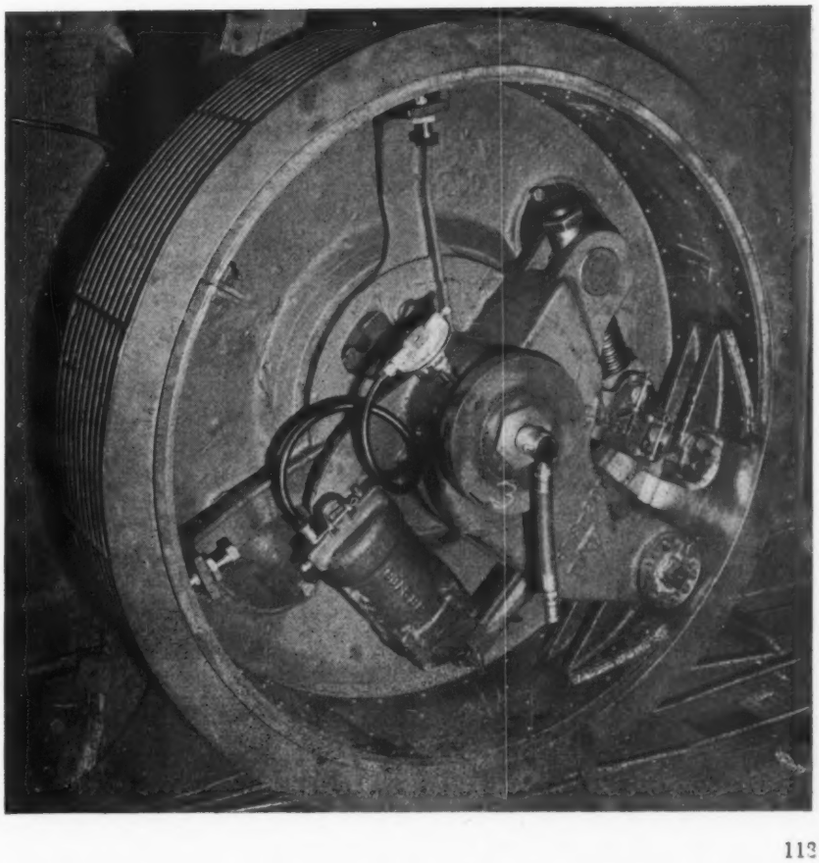


Fig. 5—Right—Typical friction clutch assembly. Loading is applied to both the live and dead ends of the band

through line 22 to a pilot valve located on the compressor. This cuts out the compressor until such time as the pressure in the reservoir drops to a set point, when the compressor again cuts in.

Compressed air from the high-pressure tank is admitted to a low-pressure reservoir through a pressure-regulator valve at 80 psi. Both high and low-pressure tanks are equipped with safety valves as shown in the diagram. Approximately 95 per cent of the moisture from the air is collected in the high-pressure tank which can be drained off periodically so that nearly-dry air is admitted to the air lines and operating valves. This eliminates collection of ice in air lines during cold weather operation. As a further safeguard along this line, an antifreezer is attached to the intake on the air compressor. Alcohol is used generally in this unit which works on the wick principle. A small amount of alcohol is mixed with the incoming air. A sufficient amount is admitted to eliminate any possibility of freezing, should sufficient moisture get past the high-pressure tank to cause trouble.

From the low-pressure reservoir compressed air is taken by supply lines to two air-supply manifolds. These manifolds are indicated in the diagram, *Fig.* 2, and are shown in the operator's compartment in *Fig.* 3. One, located in front of operator, supplies air to the main operating valves for front-hoist clutch, swing and propel clutches, boom hoist and lowering clutches, and rear-hoist clutch. The other manifold, located to right of operator, admits air to control the auxiliary functions of the machine such as shifting clutches from propel to swing and vice versa, steering, cab lock, master clutch on engine, etc. Arrangement of the clutch and brake control valves is shown in *Fig.* 4.

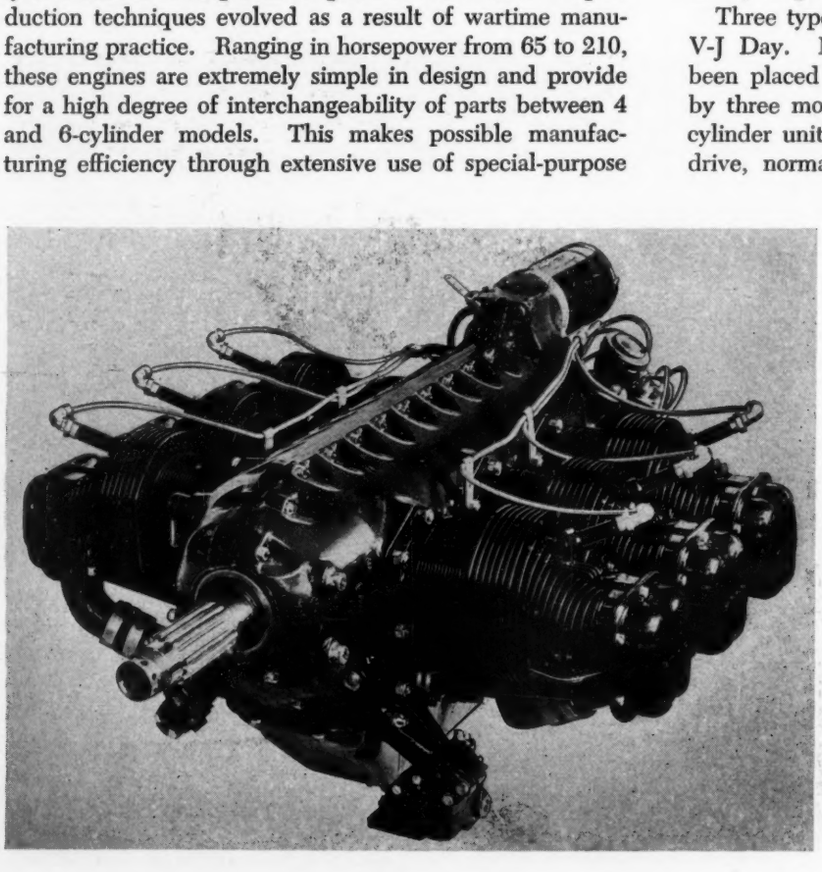
Compressed air for the two foot brakes is taken from the front manifold through air lines 18 and 19 to relay valves on air cylinders located near their respective brakes. Relay valves were found necessary in this application because of the distance from the operator's station to the hoist brakes. Time lag is eliminated by the use of relay valves, making the brakes more responsive to the valve.

For the same reason quick-release valves are located near their individual clutches. Exhaust air from the air cylinders can quickly reach the atmosphere, eliminating lag which comes from pushing this exhaust through a long line out through the exhaust valve.

Application of the air cylinders to the individual clutches which are of the internal expanding type is along conventional lines with special features applying to the application of loading to both the live and dead ends of the band as shown in *Fig.* 5. Application of air to the hoist brakes is also along conventional lines, air set and spring release. A safety feature is incorporated so that if, for any reason, the air should be lost the brake would automatically set.

Interchangeability Is Major Design Factor

ENGINEERING designs of Continental engines for powering personal planes have been worked out specifically to facilitate widespread adoption of the latest mass production techniques evolved as a result of wartime manufacturing practice. Ranging in horsepower from 65 to 210, these engines are extremely simple in design and provide for a high degree of interchangeability of parts between 4 and 6-cylinder models. This makes possible manufacturing efficiency through extensive use of special-purpose tooling, the cost of which can be amortized over greater production runs than would be possible if interchangeability of parts had not been a prime objective.



Three types of 4-cylinder engines have been built since V-J Day. More recently three 6-cylinder models have been placed in production. These will be followed soon by three more. Like the 4-cylinder engines, the new 6-cylinder units are horizontally opposed, air-cooled, direct-drive, normally aspirated engines. Except for the difference in crankcase, crankshaft and other parts occasioned by the greater number of cylinders, the 6-cylinder models embody the same general construction as the smaller engines.

Cylinder assemblies are interchangeable between those engines having the same bore and stroke, there being only two combinations. This interchangeability is carried though to other items such as piston assemblies, connecting rod assemblies, valve and rocker arm assemblies, accessory drive gears, and starter and generator assemblies.

Pistons are heat-treated aluminum-alloy castings and carry full-floating piston pins of casehardened seamless-steel tubing maintained in position by aluminum plugs fitted at each end of the pin. Valve lifters are hydraulic and eliminate all necessity of tappet adjustment. The valves are operated by rocker arms, actuated by steel-tube push rods.

Designing Computing Mechanisms

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Part VI—Servomechanisms

BASIC schematic diagram of any servomechanism or followup is shown in *Fig.* 49. The response, y, of a servo is subtracted from a weak input quantity, x, in a differential. The output of the differential, representing the difference between x and y, controls the operation of the servo. When x is equal to y, the control is at zero; when x exceeds y, the control is moved so as to cause the servo to increase the value of y, etc. The effect is to make y follow-up or reproduce x, but with all the power of the servomechanism behind it; for this reason these devices are sometimes called *torque amplifiers.*

As actually constructed, servomechanisms vary greatly in details. For example the differential, which is an essential concomitant of all servos, may not actually be a mechanical differential gear of conventional type, but its equivalent will always be present, albeit in disguised form.

As an aid in understanding the theory of servo operation, an "idealized" elementary system will be considered first. It will be assumed that the servo is an ideal variable-speed drive whose characteristics depend upon kinematic relations alone. The ball integrator would represent such a type, since its output speed is directly proportional to the position of the rate carriage only, without any time delays in the response to the rate setting. Incidentally, although it is entirely feasible to use the ball integrator as a servo, it is seldom so used, since it is expensive and bulky in comparison with the small electric servos with which it must compete. However there is a servo used to some extent which more or less closely follows the "idealized" type. This is the Nieman torque amplifier, which is fundamentally a clutch based on the principle of the self-energizing brake[20].

When used as a servo, the integrator functions exactly as it did in the time differentiator or tachometer which was discussed in the preceding section, except that now the principal concern is with the revolutions turned by the output. Let x = quantity to be followed up, and y = servo output, or response; then dy/dt = servo speed and control setting. From *Fig.* 49 it will be evident that:

$$\frac{dy}{dt} = K(x-y) \quad \ldots\ldots\ldots\

control. The foregoing equation may be written:

$$y = x - \frac{1}{K}\frac{dy}{dt} \quad \ldots\ldots (2)$$

Thus it will be seen that y will lag behind x by an amount proportional to the velocity of the servo itself. For this reason such a system is sometimes called a "straight velocity lag" follow-up. Also it will be seen that the error is inversely proportional to the sensitivity factor, K, so it is obviously desirable to make K as large as possible. In order to solve for y in terms of x and t alone, Equation 1 may be rearranged:

$$\frac{dy}{dt} + Ky = Kx \quad \ldots\ldots (3)$$

solving:

$$y = Ce^{-Kt} + Ke^{-Kt}\int xe^{Kt}dt \quad \ldots\ldots (4)$$

where the first term, Ce^{-Kt}, represents the transient. The value of the integration constant, C, depends upon the initial values of x and y. The second term represents the steady state conditions, and to evaluate it x must be expressed as a function of time. One criterion for judging the merits of any follow-up is to determine its steady state response error when the input function is changing uniformly with time. Accordingly, let $dx/dt = A$ (a constant) or $x = At$. Substituting this value of x in Equation 4, the steady state expression for y is

$$y = AKe^{-Kt}\int te^{Kt}dt \quad \ldots\ldots (5)$$

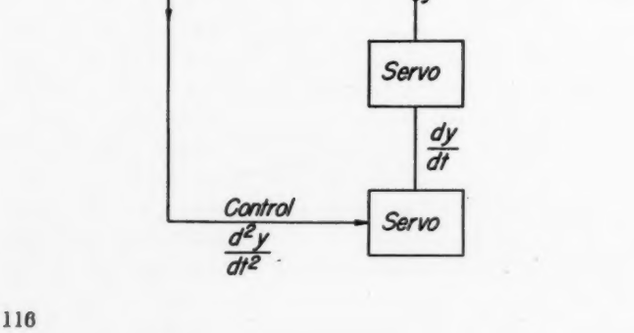
Integrating:

$$y = At - \frac{A}{K} \quad \ldots\ldots (6)$$

or

$$y = x - \frac{1}{K}\frac{dx}{dt} \quad \ldots\ldots (7)$$

Fig. 50—Schematic arrangement of straight acceleration-lag followup, obtained by compounding servos, which will hunt violently and cannot be used in the form shown



Thus it is seen that the steady-state error in y for uniform input speed is proportional directly to speed, and inversely to K, the control feed-back factor. It also is noted that $1/K$ has the dimensions of time and represents the time constant (time required for the transient to be 63 per cent wiped out).

It may now occur to the reader that it should be possible to eliminate the steady-state error (for constant input speed) by making the lag proportional to acceleration rather than velocity, by compounding followups as in *Fig.* 50. While this is valid for the steady-state error, it will be seen that it also gives rise to sustained oscillations, causing instability or hunting. In this case

$$\frac{d^2y}{dt^2} = K(x-y) \quad \ldots\ldots (8)$$

or

$$\frac{d^2y}{dt^2} + Ky = Kx \quad \ldots\ldots (9)$$

Solving for the complemental term,

$$y = C_1 \sin\sqrt{K}\,t + C_2\cos\sqrt{K}\,t \quad \ldots\ldots (10)$$

where C_1 and C_2 depend upon the initial conditions. From Equation 10 it is clear that perpetual hunting will ensue, hence a straight acceleration lag system is an impossibility, despite the frequent use of this term when other modified systems actually are meant.

However, it is possible to introduce a modicum of velocity control as shown in *Fig.* 51, and thereby either damp out the oscillations or inhibit their occurrence altogether, and at the same time eliminate the steady-state lag error. In this case

$$\frac{d}{dt}\left[\frac{dy}{dt} - K_1(x-y)\right] = K_2(x-y) \quad \ldots\ldots (11)$$

where K_1 and K_2 are the sensitivity factors of the velocity and acceleration components, respectively. Performing the differentiation indicated, and rearranging the terms:

$$\frac{a-y}{dt^2} + K_1\frac{dy}{dt} + K_2 y = K_1\frac{dx}{dt} + K_2 x \quad \ldots\ldots (12)$$

From this equation it is evident that under steady-state conditions ($d^2y/dt^2 = 0$ and dx/dt constant), y will equal x; also that the transient will be damped by the presence of the $K_1\,dy/dt$ term. Solving for the transient:

Case I, $K_1 < 2\sqrt{K_2}$ (underdamped)

$$y = e^{-K_1 t/2}\left(C_1 \sin\sqrt{K_2 - \frac{1}{4}K_1^2}\,t + C_2\cos\sqrt{K_2 - \frac{1}{4}K_1^2}\,t\right) \quad \ldots\ldots (13)$$

Case II, $K_1 = 2\sqrt{K_2}$ (critically damped)

$$y = e^{-K_1 t/2}(C_1 + C_2 t) \quad \ldots\ldots (14)$$

Case III, $K_1 > 2\sqrt{K_2}$ (overdamped)

$$y = e^{-K_1 t/2}\left(C_1 e^{+\sqrt{1/4 K_1^2 - K_2}\, t} + C_2 e^{-\sqrt{1/4 K_1^2 - K_2}\, t}\right) \quad \ldots\ldots (15)$$

In Cases II and III no oscillation whatever will occur. This type of followup might be called "damped acceleration lag" or "short period velocity lag" control, because the velocity lag error is wiped out eventually if the input quantity has a constant speed.

More Complex Systems: Discussion thus far has been confined to servomechanisms having characteristics like those of the ball integrator. The characteristics of a mathematically more complex type will now be examined. *Fig.* 52 shows a follow-up containing a d-c motor having a separate fixed source of field excitation, and its armature fed by a generator driven by any suitable prime-mover. The field excitation of the generator also is supplied from a separate source, but is controlled by a potentiometer in such a way that the steady-state motor speed is proportional to the potentiometer handle setting. The handle is positioned by the output of a differential subtracting the response from the input quantity in the usual manner. This arrangement of generator and motor is sometimes called the Ward-Leonard system. Generator-motor combinations employing special features such as crossed-axis field amplification are basically similar.

Delay Characteristics of System

Superficially this system resembles the idealized "velocity lag" followup described first, but now two important time delays enter the problem. One is the delay in building up the generator field excitation in response to a change in potentiometer setting, due to the inductance of the field. The second is the ballistic delay of the motor in reaching the speed corresponding to the generator emf, due to the inertia of the motor armature and its connected load. These two delays are of a similar mathematical nature and may be represented by exponential time constants. The motor armature inertia time constant is essentially constant, being dependent principally upon the inertia and the armature circuit resistance, which does not change materially. The generator field time constant may vary somewhat, since it depends upon the field inductance, which is a function of the degree of saturation, and also upon the field circuit resistance, which may be affected by the potentiometer setting. However, these two effects tend to cancel each other to some extent; furthermore, since stability is the main interest, only small changes in field strength about a given setting are involved, and for this the field time constant can be regarded as a constant, although it may have different numerical values at different speed settings. If T_1 = generator field time constant, T_2 = motor armature time constant, n = motor speed, and v = generator field

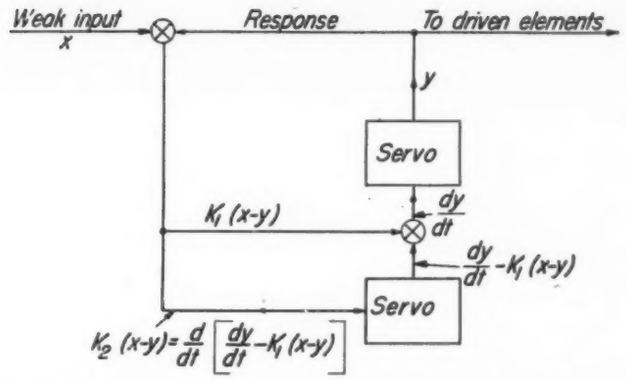


Fig. 51—Diagram of damped acceleration-lag followup, a modification of Fig. 50, which overcomes the objections to the simple velocity-lag or acceleration-lag systems

voltage, it can be shown that:

$$T_1 T_2 \frac{d^2 n}{dt^2} + (T_1 + T_2)\frac{an}{dt} + n \propto v \quad \ldots\ldots (16)$$

assuming the friction load on the motor to be constant, which is normally the case. However, $n \propto dy/dt$ and $v \propto (x - y)$, therefore

$$T_1 T_2 \frac{d^3 y}{dt^3} + (T_1 + T_2)\frac{d^2 y}{dt^2} + \frac{dy}{dt} = K(x - y) \quad \ldots\ldots (17)$$

where K represents the control sensitivity factor, or

$$T_1 T_2 \frac{d^3 y}{dt^3} + (T_1 + T_2)\frac{d^2 y}{dt^2} + \frac{dy}{dt} + Ky = Kx \quad \ldots\ldots (18)$$

Whether or not the followup will be stable depends upon the form of the complemental, or transient, term of the solution of this equation. Forming the auxiliary algebraic equation

$$T_1 T_2 p^3 + (T_1 + T_2)p^2 + p + K = 0 \quad \ldots\ldots (19)$$

or

$$p(T_1 p + 1)(T_2 p + 1) + K = 0 \quad \ldots\ldots (19a)$$

If all roots of Equation 19 are negative and real, the drive is stable and nonoscillatory; if two roots are complex with *negative* real components, the drive is stable but will have a damped oscillatory transient; if two roots are purely imaginary, the drive is on the threshold of instability (continuous hunting); while if two roots are complex with *positive* real components, the drive will hunt with ever-increasing amplitude. It is evident that the sensitivity factor, K, must be chosen so that the drive will be stable. The limit will obviously be the value of K that just barely causes continuous oscillation (two roots purely imaginary). Suppose these roots to be $\pm ja$ (frequency of oscillation = $a/2\pi$). Substituting one of these roots, say ja, in Equation 19, the following equation is obtained:

$$-jT_1T_2a^3-(T_1+T_2)a^2+ja+K=0 \quad \ldots\ldots (20)$$

Since the sums of both the real and imaginary terms must each equal zero:

$$-T_1T_2a^3+a=0$$

or

$$a^2=\frac{1}{T_1T_2} \quad \ldots\ldots (21)$$

and

$$-(T_1+T_2)a^2+K=0$$

or

$$K=(T_1+T_2)a^2 \quad \ldots\ldots (22)$$

Eliminating a^2 between Equations 21 and 22:

$$K=\left(\frac{1}{T_1}+\frac{1}{T_2}\right) \quad \ldots\ldots (23)$$

From Equation 23 it is evident that it is desirable to make time constants T_1 and T_2 as small as possible in order to have the sensitivity factor as large as possible. In fact if T_1 and T_2 are both zero, Equation 18 reduces to that for the "idealized" velocity lag followup, Equation 3, in which K can have any value whatever without causing oscillation.

Since it might be instructive to know the relative magnitudes of the various constants involved in a typical installation, an example which came within the writer's experience will be cited. This drive was designed for about one horsepower, and had the following characteristics: Top speed of motor = 6000 rpm, generator field time constant, T_1 = 1/150-sec and motor armature time constant, T_2 = 1/30-sec. The control sensitivity factor, K, which will just put the drive on the verge of instability is, from Equation 23,

$$K=\frac{1}{T_1}+\frac{1}{T_2}=150+30=180$$

or slightly less for stability. Thus, $1/K$ is 1/180-sec. Under steady-state conditions with the drive running at constant speed, d^3y/dt^3 and d^2y/dt^2 are both zero, so Equation 18 reduces to:

$$\frac{dy}{dt}+Ky=Kx$$

and the error is

$$x-y=\frac{1}{K}\frac{dy}{dt} \quad \ldots\ldots (24)$$

At top speed (6000 rpm), dy/dt = 100 rps, therefore maximum steady-state lag error = 1/180 × 100 = 5/9 revolution, but the drive is on the threshold of sustained oscillation.

On the other hand a followup may be desired that has not even a transient oscillation (dead beat). In this case Equation 19 must have only negative real roots. Substituting the foregoing values of T_1 and T_2:

$$\left(\frac{1}{30}\right)\left(\frac{1}{150}\right)p^3+\left(\frac{1}{30}+\frac{1}{150}\right)p^2+p+K=0$$

or

$$p^3+180p^2+4500p+4500K=0$$

The highest value of K occurs when two of the roots are equal. Let these be $-a$ and the third root $-b$. Then:

$$(p+a)^2(p+b)=0$$

$$p^3+(2a+b)p^2+(a^2+2ab)p+a^2b=0$$

Hence:

$$2a+b=180$$

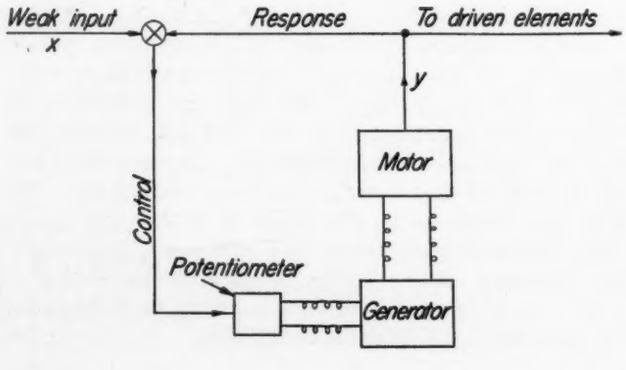
$$a^2+2ab=4500$$

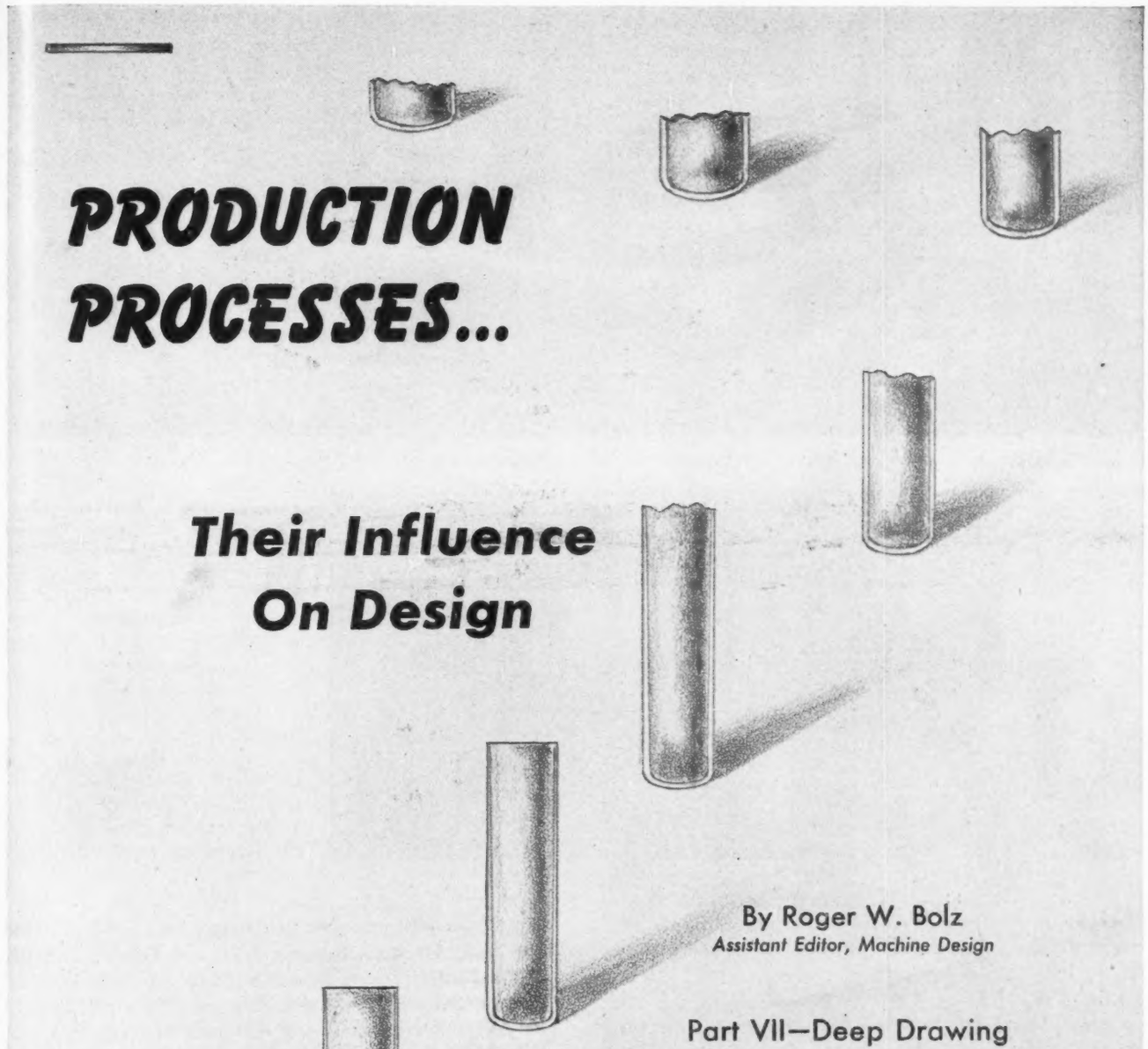
or, a = 14.174 and b = 151.65, therefore: a^2b = 30,468 = 4500 K, from which K = 6.7707. Maximum steady-state lag error = 100/6.7707 = 14.77 revolutions of motor shaft.

In some types of Ward-Leonard drives the generator field is not controlled directly, but is energized by an exciter whose field is in turn controlled. This puts an additional time constant in the chain, the exciter field time constant, which adds another term to the characteristic speed equation of the motor (Equation 16), and raises it by one order. Additional relay exciters will have a like effect, the

(*Concluded on Page* 180)

Fig. 52—Ward-Leonard type followup in which the control operates a potentiometer in the field circuit of a d-c generator supplying current to a motor





PRODUCTION PROCESSES...

Their Influence On Design

By Roger W. Bolz
Assistant Editor, Machine Design

Part VII—Deep Drawing

ALLIED closely with the various punch press operations outlined previously under the general term "stamping" is the process of deep drawing. Unquestionably this production method parallels stamping in its importance as a vital source of low-cost machine parts. Often used in conjunction with one or more of the various stamping operations, the combination has become in many aspects synonomous. Effects of deep drawing requirements and limitations upon the design features of parts which fall within the scope of this method of forming metal consequently necessitate careful consideration by the designer to assure maximum economy in production.

Basically, drawing or deep drawing is a stretching process. Sheet is stretched over or drawn into a die to conform it to the required shape. A blank holder is usually used to retain the blank form while drawing. As this takes place, the portion of the blank clamped by the blank holder is drawn in and its circumference is reduced. Severe compressive stresses produced by this shrinking in the size of the blank tend to produce wrinkles on light gage sheet and so necessitates high holding pressures. Heavy gage

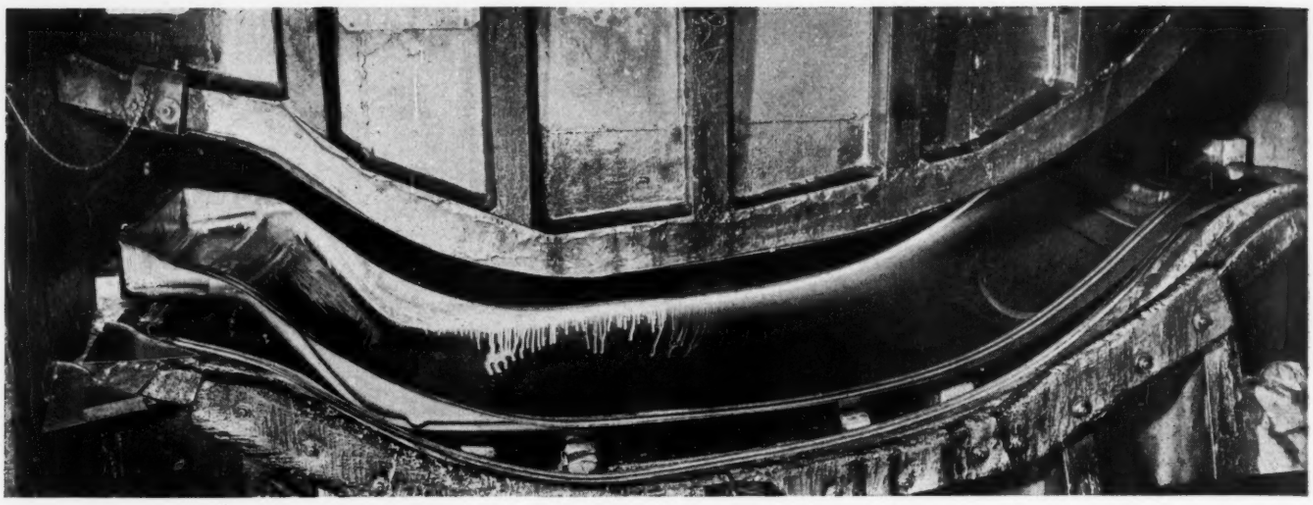


Fig. 1—Above—In the production of large, irregularly shaped parts such as this turret automobile top, closely controlled stretching of the metal sheet is imperative

Fig. 2—Left—Using SAE 1010 hot-rolled, pickled-in-oil stock, this booster casing is deep drawn, tapered, upset, and sized for threading in 9 operations

blanks, however, assimilate this shrinkage readily and consequently are easier to hold. In many cases heavy blanks require no blank holder at all.

Controlled stretching by means of controlled blank holding is highly advantageous and often necessary in drawing large size irregular shapes, *Fig.* 1. In such cases where stretching must be controlled to an extent greater than that normally available by means of the blank holder, draw beads or raised moldings are used to retard the metal movement. These are visible on the part shown in *Fig.* 1.

Drawing operations include the drawing and redrawing of all sorts of shapes and in addition sizing, ironing, and like forming work on certain parts. Machine parts are produced on the ordinary types of draw presses from practically all metals—cold formed in thicknesses up to about 3/4-inch and hot up to about 3 1/2-inches. In general, with a good deep drawing steel, a round blank can be drawn in one operation so that the resulting cup diameter is 40 to 50 per cent that of the original blank. Blanks to be subsequently redrawn are usually limited to 55 to 60 per cent or in other words a 40 to 45 per cent reduction on the first draw. Irregularly shaped parts such as the steel automobile top shown in *Fig.* 1, are limited to a draw which produces a maximum elongation of 40 per cent. Normally, draws requiring over 33 per cent elongation of the steel at any point need special handling or working.

On simple redraw work planned for single-action presses, reductions ordinarily considered as practical for production are as follows: For steel stock up to 1/16-inch in thickness, 20 per cent reduction in diameter over that left by the first draw; for stock between 1/16 and 1/8-inch, 15 per cent reduction; for stock between 1/8 and 3/16-inch, 12 per cent reduction; for stock between 3/16 and 1/4-inch, 10 per cent reduction; and for stock between 1/4 and 5/16-inch, 8 per cent reduction. Large production redraws which can be performed in more costly double-action dies allow an increase of approximately 50 per cent over these reductions. Quality deep drawing brass stock drawn in single-action presses likewise shows about a 50 per cent increase.

Depth of Draw Restricted

Ordinarily cups or tubes can be drawn satisfactorily to a depth 6 to 8 times their diameter in production. However, a plain cylindrical shell should seldom be drawn to a depth greater than three-fourths its diameter in one draw, although in a double-action die it is possible to make the depth equal to the diameter in one draw. In hot-drawing magnesium, cylindrical cups can be drawn to a depth 1.5 times their diameter in one operation. Physical properties of materials used, of course, may increase or restrict these depths. Shells with a flange at the top are restricted to shallower depths. Parts formed to a depth greater than 6 to 8 times their diameter by means of redrawing will often have to compete with similar designs based on seamless or welded tubing. Nevertheless, with parts requiring ironed or accurately sized walls, annealing

and redrawing can be utilized to obtain far greater depths. To illustrate the range of possibilities a blank of deep drawing steel 9 inches in diameter by 0.035-inch gage was drawn to 0.750-inch diameter by 32 inches deep. Wall thickness was maintained at 0.035-inch throughout the part.

Production of deep tapered shells or those with tapered walls are usually difficult to draw and require numerous operations. The high output per hour and accuracy obtainable, however, once dies are made, *Fig.* 2, maintain low-cost production where large quantities are needed.

In many cases production deep drawing of parts ordinarily machined from solid stock can afford considerable savings in both time and materials, *Fig.* 3. On many parts such as that shown in *Fig.* 3 tapering, necking, sizing, profiling and upsetting can be used to advantage to obviate machining operations. Although this part was threaded on the screw machine, roll threading can often be utilized to reduce costs still further when the wall thickness is sufficiently heavy to withstand the operation.

Where necking is undesirable or impractical on certain parts, expanding or bulging is often resorted to. This can be accomplished in metal dies, rubber dies or hydraulic dies. Bulging work is limited to a maximum increase in diameter of about 30 per cent in one operation. Bulges greater than this require additional steps and annealing.

Burring—turning out a flange around a hole in some particular portion of a drawn shell or sheet—is directly opposite to the necking operation. Rather than compressing the material, it is put entirely in tension. Metal, instead of being drawn in from the outside, is drawn out from the inside. Usually a center hole is punched which is small enough to permit raising a wall of sufficient height. To assure a smooth burr, the circumference or diameter of the punched hole should not be stretched over 30 per cent. For such a stretch the height of flange which can be raised in one draw is about one-tenth the finished diameter of the burr. Higher burrs are obtained by ironing or thinning out the walls and also by first drawing the metal into a cup, then punching a hole in the bottom and finally throwing out the remainder of the burr to finish.

Logically falling under the deep drawing press operations are also those of rubber-die forming and stretch forming—both basically stretching processes. These operations are usually performed on special machines using special dies. Each, however, has assumed a major place in the mass production of parts which were unsuitable for the other methods.

The rubber-die forming process, known as the "Guerin Process" utilizes dies of any material with sufficient toughness to stand up under the working pressures involved. Plastics, low-cost alloys, impregnated fiber, and wood can be used. For greatest life as well as for intricate parts, metal dies are required. Dies are cheap, easy to produce and require no fitting. The rubber pad mates with the die regardless of form, shape or size. Shearing as well

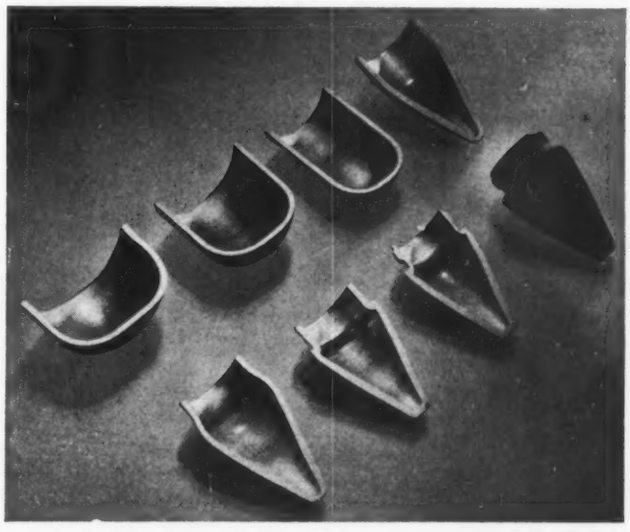


Fig. 3—Right—This dummy fuze for a 37 MM shell was converted from a machined aluminum casting to SAE 1010 steel drawn from a 3.25-inch diameter blank, 0.083-inch thick. Operations: Blank and first form; anneal; first redraw—correct thickness of material; second redraw—thin walls; trim length; taper; first necking; second necking; third necking—size, profile, store metal in shoulder, and square corners; prepare for threading; thread

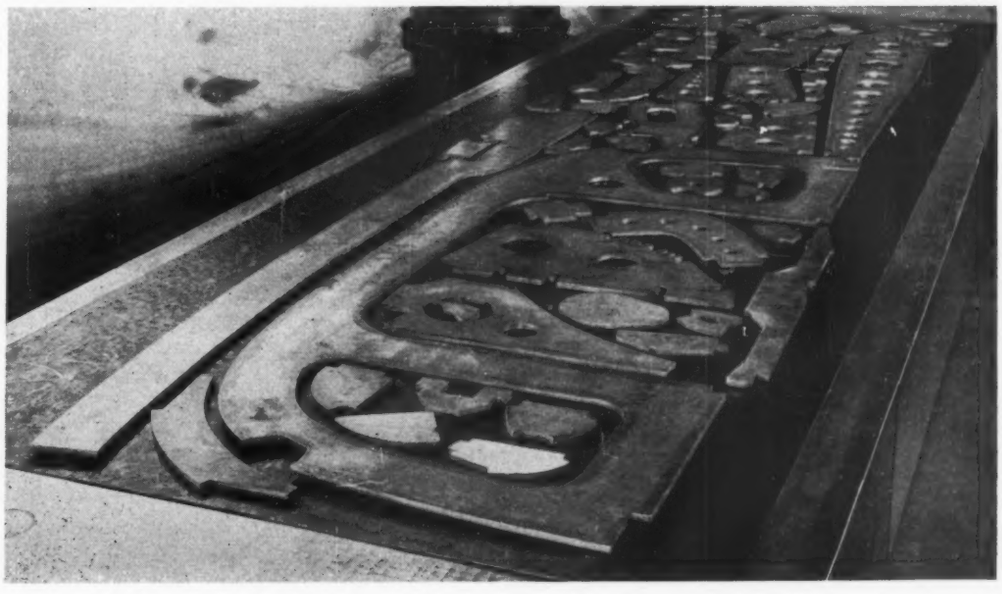


Fig. 4 — Right — Many different parts can be cut or drawn from one sheet by the rubber-die process. Sixty-six parts are blanked at once in the setup shown

as drawing is possible. In some cases parts can be blanked and formed in one operation.

Ideal where large quantities of a variety of machine parts are needed constantly, a great many different parts can be formed or drawn at the same time, *Fig.* 4. At each loading of the platen, a full-sized sheet of metal can be cut or pressed into parts. In normal operation over 15,000 parts such as shown in *Fig.* 5 can be produced in 8 hours. No lubricants are used and the parts emerge clean, eliminating a degreasing operation.

Rubber-die forming is successfully used for the drawing of aluminum and aluminum alloys, light-gage mild-steel sheet, stainless-steel sheet, copper, and magnesium alloys. A minimum pressure of 1000 psi is required for working simple aluminum shapes. Greater pressures make for more perfect draws, especially with complicated parts. Hydraulic presses are considered best for this process and those now in use range from 1000 to 5000 tons capacity.

Not unlike the rubber-die process is the drawing of metals on the stretch press. Flexible low-cost tooling for the production of large quantities of parts which require continual design changes is the primary feature. Adapted to the economical fabrication of extreme double-curvature parts, this method is usually considered as intermediate between the drop hammer and the large, high-production draw press. Occasionally parts can be produced satisfactorily on no other machine.

Chief limitation is that only contours relatively symmetrical and with only slight reverse bends can be drawn, *Fig.* 6. In addition, a high percentage of scrap—as much as one-third the material used—is unavoidable. Each end must be clamped for stretching. Common practice dictates an average of 16 inches must be added to the length and 2 inches to the width of a part for trimming. Scrap loss can be reduced, however, by producing two or more parts simultaneously on the same die wherever possible.

Drawing of sheet in the stretch press elongates the material and ordinarily reduces its thickness from 5 to 7 per cent. However, the increase in tensile strength resulting from stretching usually more than compensates for the reduction. Only designs which require about 8 per cent elongation (maximum 12 per cent) can be handled successfully. Nonuniform parts may be produced on the stretch press if the cross-sectional area remains constant, variation being in shape only.

Reverse contours, *Fig.* 6, can be formed if dies are designed to overcome wrinkling. Draw beads are used to hold the material from slipping at reverse curvatures. Proper use of lubricant is also effective in controlling re-

Fig. 5—Below—Typical variety of machine parts fabricated by the rubber-die process with low-cost tooling

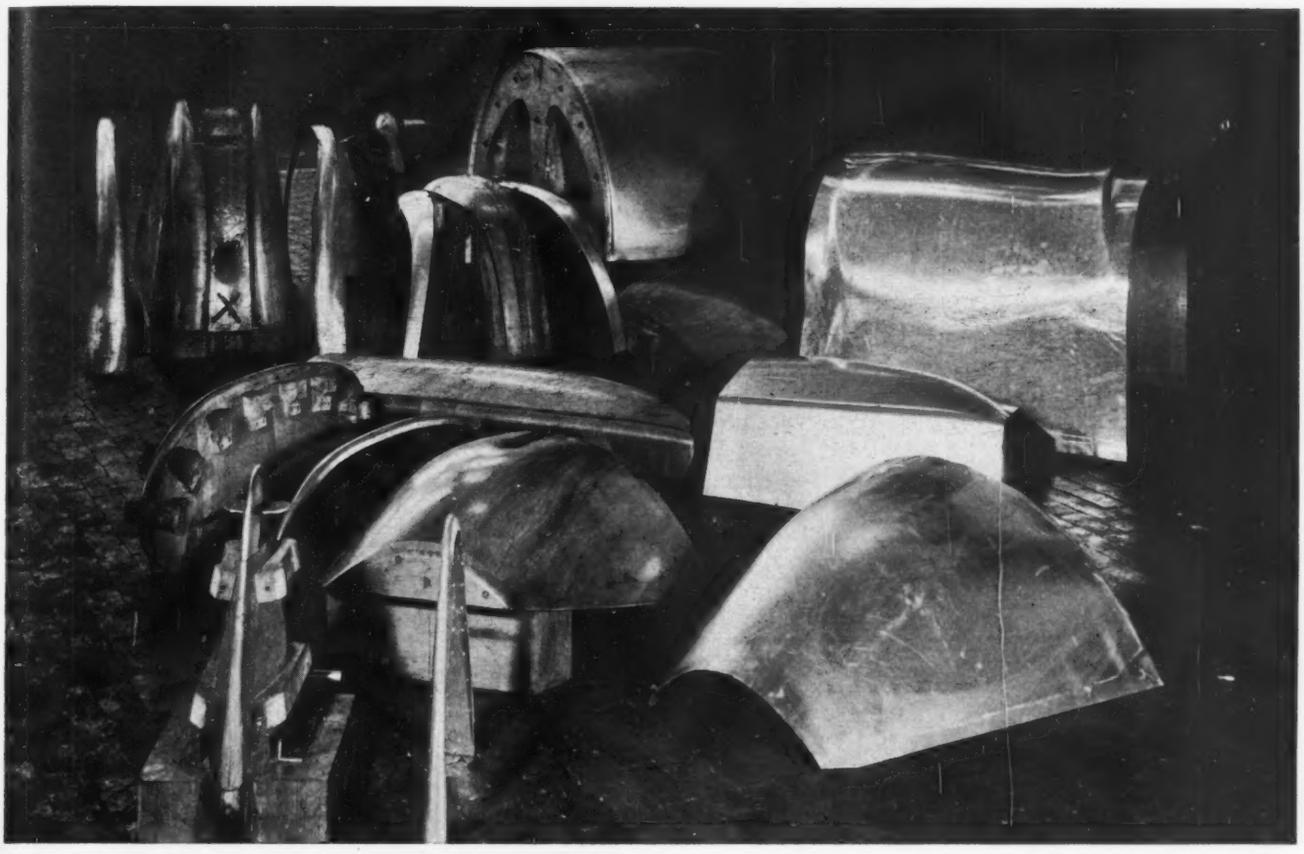


Fig. 6—Variety of stretch forming dies and aircraft parts produced on the stretch press

verse bending and wrinkling. Lubricant action such as that provided by vaseline or drawing compound is always required. Lately, however, rubber sheets have been used over the die with superior results. Marking or scratching and the problems of degreasing are entirely eliminated.

Die materials for stretch forming are Kirksite, concrete faced with plaster and hardwood. Lead, iron and fiber have also been used occasionally.

DESIGN: A specific drawn part may be produced, as a general rule, by various ones of the great number of different types of machines available for drawing metal. Modification will usually adapt the design required to make possible satisfactory manufacture by other available methods. However, careful consideration of all the factors involved will usually indicate one particular method or machine for maximum efficency.

Large-quantity drawn parts of definite design are most economically produced on the high-speed mechanical press. Plain shapes and sections with both uniform and nonuniform curves or contours—parts which can be drawn in a single operation are ideal for these presses. The more complicated parts—extremely deep-drawn parts especially those with unusual shapes and difficult contours, *Fig.* 1—are best suited for production on double or triple-action mechanical presses. Deep drawn cylinders or parts with uniform cross sections especially in stainless steels, are often produced most easily on hydraulic presses owing to the controllable, uniform drawing speeds.

Following rules somewhat similar to those outlined in the previous article on stampings, cost of drawn parts likewise can be kept to a minimum by maximum simplicity of design. Round cross sections are by far the simplest to produce while square, rectangular or irregular cross sections involve greater difficulties in both die sinking and production. Shells having integral flanges generally involve higher manufacturing costs and tool maintenance than those without flanges. Shells without flanges create about one-half the die wear and can be drawn at a much faster rate. To draw either flanged or plain shells near or at the maximum permissible reduction percentage, radii in the bottom and under the flange should be adequate.

Drawing Radii are Critical

Radius of the drawing edge of a die—that radius under a flange—if too large tends to create wrinkles in the material while if too small will tend to tear the metal. This radius and that at the bottom of a shell should be governed largely by the gage of the material. Radii for stock 28 to 26 U. S. gage should be 5/32-inch (minimum) to 1/4-inch (maximum), 25 to 23 gage should be 3/16 to 5/16-inch, and 18 to 16 gage stock should have radii from 1/4 to 3/8-inch. Sheet over 16 gage (0.0625-inch) should have radii at least 6 times the gage size and these radii can be increased somewhat for most satisfactory operation. Draw edge radii for stainless steels may be reduced to 2.5 times the gage and for magnesium and most aluminum alloys should be greater than 6 times. In Monel, nickel and Inconel, the radius should be from 5 to 12 times the gage. Large radii are especially desirable on parts drawn from heavy-gage plate. Where smaller radii are necessary extra operations are usually required to achieve satisfactory production. Deep drawings over one diameter in depth often can have these radii reduced on successive draws.

Corner radii of rectangular or square shapes are of

Fig. 7—Left—Generous corner, flange and bottom radii are required for aluminum parts produced by the rubber-die process

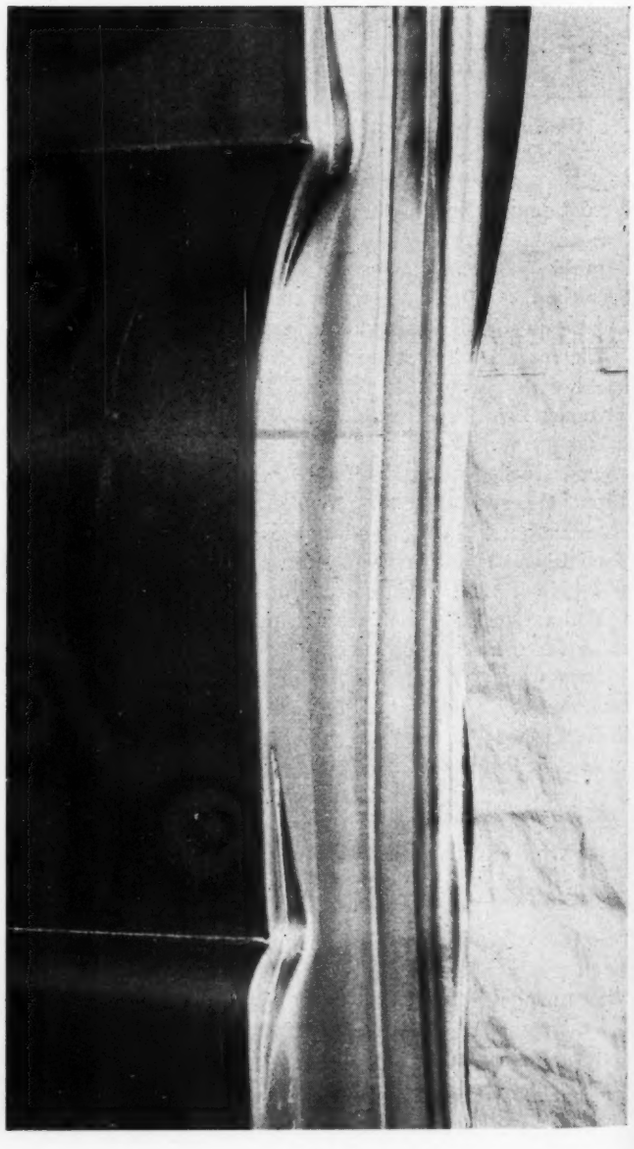
Fig. 8—Below—Indentations or depressions provide the necessary stretch to take up excess metal and avoid wrinkles

primary importance. Satisfactory production is entirely dependent upon these radii and the material used. Steel boxes over one-half their width in depth should be made from deep drawing material. Corner radii should be as large as possible and at a minimum 5 times the gage. Flange and bottom radii under 3/4-inch usually require more than one operation. In a good drawing material such as brass, boxes can be drawn to 6 times the corner radius in one operation. In other materials, depth in one draw will be somewhat less than 6 times depending upon the elongation characteristics. Parts designed for rubber-die forming likewise require generous corner, bottom and flange radii, *Fig.* 7. Notches in the blank along outside bend contours are sometimes required, *Fig.* 5, to obviate wrinkling which results from lack of sufficient blank holding action exerted by the upper rubber-die pad.

Depressions or raised pads should be no greater than is necessary. A good rule is not to exceed two times the gage in depth. Deeper pads or depressions are often possible in deep drawing materials but require generous radii all around.

Drawn parts having hemispherical or curved bottoms should be avoided in favor of those with substantially flat bottoms. Unless design benefits are gained by such deeply curved bottoms and elongations over 33 per cent the higher production costs involved are hard to justify. Parts such as modern automobile fenders, doors, hoods, tops, etc. fall into this category and usually entail much research and special handling technique for successful production. Such parts are often tested out in quarter-size dies to determine the practicability of the design. By drawing sheet in these test dies which is about one-third the required gage of the full-sized part a very accurate check is made. Design changes can then be made before the final production dies are ordered.

For successful deep drawing of these irregular parts, the area of a blank at the holding plane must be less than the overall area of the part to assure the necessary stretch. Wherever even small amounts of compression are necessary



wrinkling will usually occur. To avoid this general practice is to provide take-up depressions to assure ample stretch, *Fig.* 8. Relief is often necessary for successful production of unusual shapes, *Fig.* 9. Shearing through sections to be blanked out on finishing operations relieves the strain of the draw sufficiently so that elongations much greater than 40 per cent can be handled. To obviate tearing of the entire sheet the shearing, however, must be timed properly to take place when the draw is from 60 to 70 per cent complete.

Layout of holes, tabs, bends, perforations, etc., are governed by much the same procedure as was previously outlined in the discussion on stampings.

Parts to be produced on the stretch press necessarily must be as simple as possible. Reverse curves parallel to the stretch are best avoided to simplify production, those normal to the direction of stretch being impractical. Inside radii of parts should not be less than 1-inch for successful stretching. Larger radii are more desirable. Edge condition of sheet or blanks to be stretched is often critical. Rough sheared edges allow only small stretches but polished or routed edges make possible maximum working of the metal without undue failure from stress concentrations.

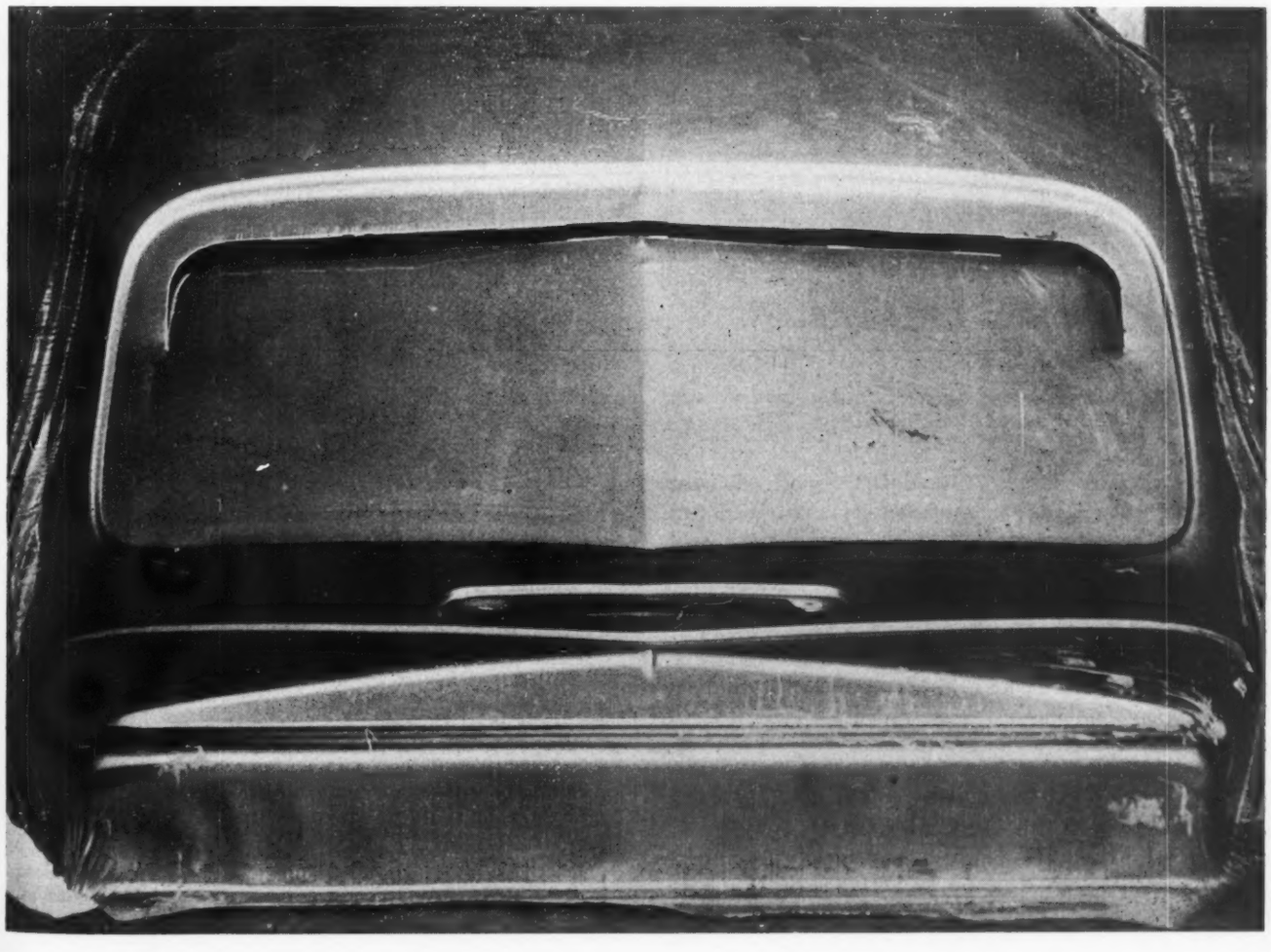
MATERIALS: Relative suitability of materials discussed in the previous article on stamping apply equally to drawing. Preferred steel for drawing, especially deep work, is of course high-quality deep drawing sheet. Draws requiring up to 33 per cent elongation of the material are easily produced and depending upon the material, design and technique this can often be raised to around 40 per cent. Preferred hardness of this sheet is about Rockwell B40 to B50.

For maximum drawability, 19-gage sheet when pressed by a 7/8-inch ball into a 1-inch female die having a 1/16-inch radius on the drawing edge, should draw to a depth of approximately 0.425-inch. This represents about a 40 per cent elongation. However, most production-run sheet now available will draw successfully only to about 0.400-inch. In normal production of irregular automotive parts a test depth of 0.415 to 0.420-inch is desirable.

Typical ductility (depth of cup) values at the point of fracture for No. 19 gage (0.0437-inch) soft sheet are as follows: Deep-drawing steel, 0.413-inch; extra deep-drawing steel, 0.433-inch; folding or tinned sheet steel, 0.397-inch; aluminum, 0.402-inch; deep drawing brass sheet, 0.563-inch; copper, 0.472-inch; zinc sheet, 0.323-inch.

Cold-rolled sheet for drawing should be specified on a weight basis giving widths in inches, length in feet and gage in decimals of an inch. Type of edge and tolerances on width and thickness are important. Type of surface or surface finish required should be specified for the job—bright, extra-bright, nickel plate, blued, rustproofed, leaded, tinned, hot or electrogalvanized, or copper plated. Extra deep-drawn steel parts or parts requiring unmarred smooth

Fig. 9—Below—Relief cuts at critical spots in sections to be blanked out reduces strain and makes ordinarily excessive elongations possible



surfaces are as a rule copper plated before drawing. The copper tends to lubricate the material during drawing and prevent scoring.

Magnesium can be handled hot most easily by the rubber-die process using special heated platens on which the form dies are set. Heat is transferred to the die and then to the magnesium sheet. Special synthetic heat-resistant rubber is required in the upper die platen. Present synthetic rubber pads will withstand operating temperatures up to 450 F. Some simple deep draw parts are being produced in special dies on mechanical presses. However, applications to date are rather limited. Reduction in one hot draw may run as high as 65 per cent.

In single-action unrestrained drawing, brass sheet can be handled faster than any of the other metals. Speeds as high as 200 fpm can be used. This drops to about 100 fpm on double-action drawing and to about 70 fpm for ironing or burnishing. Steels can be handled at drawing speeds up to 55 fpm in single-action and 35 to 50 fpm in double-action dies. Ironing or burnishing is done at speeds up to 25 fpm. In steel dies pick-up troubles are encountered at higher speeds. However, with carbide dies speeds can be considerably higher. Copper and zinc can be handled at drawing speeds up to 150 fpm in single-action and 85 fpm in double-action lies. For soft aluminum

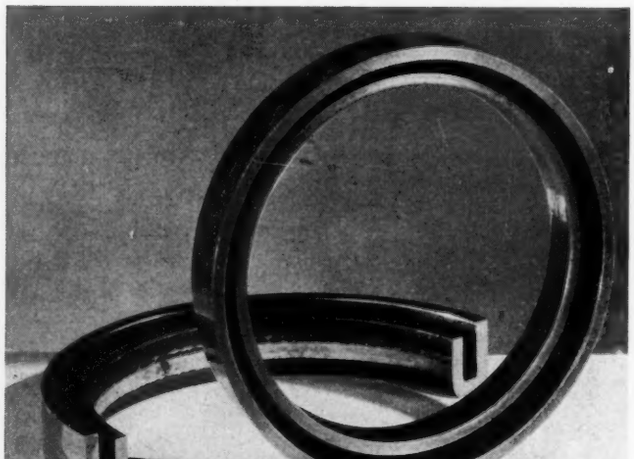


Fig. 10—Oil seal retainer, a difficult drawing and ironing job, is held to high accuracy

alloys drawing speeds are 175 and 100 respectively (the strong alloys about half). Stainless steels must be drawn somewhat slower than ordinary steels, say 20 to 25 fpm, to reduce work hardening effects. Magnesium is drawn at slow speeds of 7 to 17 fpm, the lower speeds for the thicker sheets.

TOLERANCES: Tolerances normally held in production of drawn parts are in many cases closely linked with those found under stamping. Widest practical tolerances, of course, promote economy in production.

Extremely close tolerances on shells demand tight dies producing excessive wear and difficult stripping where flanges are encountered. Although tolerances of plus or minus 0.005-inch can be held on diameter of shells up to around 6 inches with sheet up to 1/16-inch in thickness, around plus or minus 0.010-inch on those from sheet up to 1/8-inch, and plus or minus 0.015-inch on those from sheet around 1/4-inch, irregular, rectangular, or square shells require tolerances about 20 per cent greater. Of course, closer limits can be obtained in any case by redrawing, ironing or sizing as extra operations. Weight tolerances under 0.1-ounce per ounce is held on the shell in *Fig.* 3 and dimensional tolerances are held with a total variation of 0.005-inch.

Shells 4.250 inches in outside diameter drawn 4 inches deep from 0.050-inch stock are held in production to plus or minus 0.001-inch. A light ironing is required to hold this dimension. Light ironing to produce a smooth finish as well as accurate diameters and wall thickness usually can be achieved by using stock several gage sizes heavier than the thickness of the finished shell. However, ironing adds considerably to the pressure of the punch on the bottom of the shell and thus reduces the possible diameter reduction. Since diameter reductions often must be reduced by one-half to achieve high accuracy and extra fine finish by ironing, production is drastically reduced and cost consequently much higher.

Wide Tolerances Reduce Costs

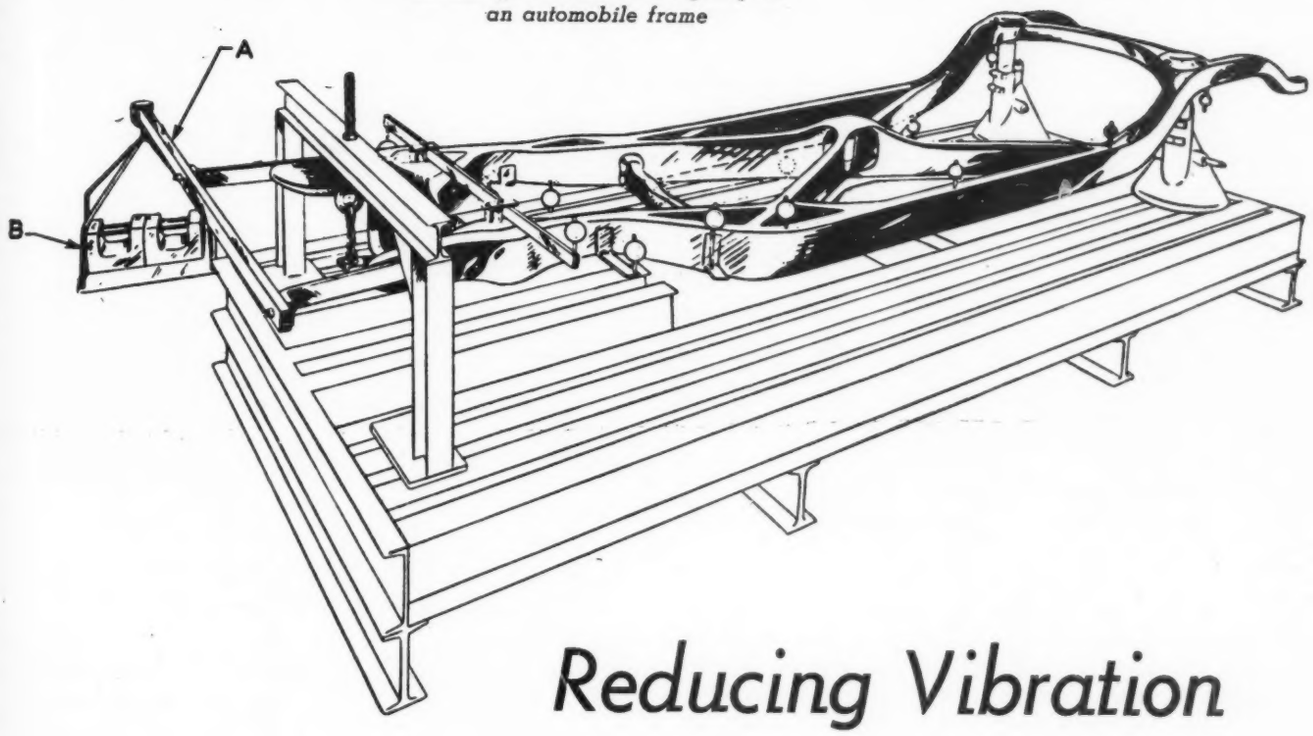
Ordinarily, without ironing, wall thickness of shells drawn from regular steels may vary from 10 to 20 per cent from the bottom to the top, thickening especially in the flange as noted previously. To reduce friction between stock and the surfaces of a punch and die for production purposes, greater clearances are allowed and thickening at the top of shells may run over 30 per cent. Aluminum drawn freely without ironing usually runs around 25 per cent.

The oil seal retainer shown sectioned in *Fig.* 10 is a good illustration of the achievement of high accuracy. Required total variation on the slot width was 0.003-inch. Total runout on the inside and outside flanges was to be no greater than 0.006-inch. To hold these tolerances the inside flange was drawn first, then the outside—in two operations to reduce tool pressures—and finally the sides were ironed to size. Cost was one-third less than that of the same part machined from a casting.

Extremes of accuracy are found in such drawn parts as cylinder liners for internal combustion engines. Drawn and ironed to an accuracy and fine finish that requires no further processing besides heat treating, such parts obviously justify expensive dies and tooling. However, if plus or minus 0.001-inch is desired on highly precise, average-size work, it should be remembered that plus or minus 0.002-inch or even 0.003-inch with larger tolerances on dimensions greater than 5 inches can greatly alleviate production problems. Tolerances around plus or minus 0.010-inch or greater wherever possible, are much easier to handle and naturally make highly successful mass production at minimum cost.

Collaboration of the following organizations in the preparation of this article is acknowledged with much appreciation;
Acklin Stamping Co. (*Fig.* 2) ..... Toledo, Ohio
American Steel & Wire Co. ..... Cleveland
Douglas Aircraft Co., Inc. (*Figs.* 4, 5 and 7) Santa Monica, Calif.
Dow Chemical Co. ..... Midland, Mich.
Engineering & Research Corp. (*Fig.* 6) ..... Riverdale, Md.
Ford Motor Co. (*Figs.* 1, 8, and 9) ..... Detroit
International Nickel Co., Inc. ..... New York
Nagle-Chase Mfg. Co. (*Fig.* 3) ..... Chicago
Pressed Metal Institute ..... Cleveland
Worcester Pressed Steel Co. (*Fig.* 10) ....Worcester, Mass.

Fig. 1—Fixture employed for determining the torsional rigidity of an automobile frame



Reducing Vibration in Passenger Cars

By Lloyd E. Muller
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IN TESTING experimental motorcars, both in the laboratory and on the road, only slight relationship could be established between the static strength or rigidity of the car and the "feel" of the car on the road. A car would appear to be very rigid when tested statically in the laboratory and yet would have all the characteristics of a "bowl of jelly" when driven on the road.

This discrepancy was disconcerting to say the least. To add to the embarrassment, the corrective for the trouble was usually not the addition of I-beams to the frame, but some minor change in the motor mount. While these experimental cars always attained the state of acceptability before the production dead-line date had been reached, they did cause headaches. Even after the cure had been effected, it was not known why; and the cure did not always work in the case of the next model car upon which it was tried.

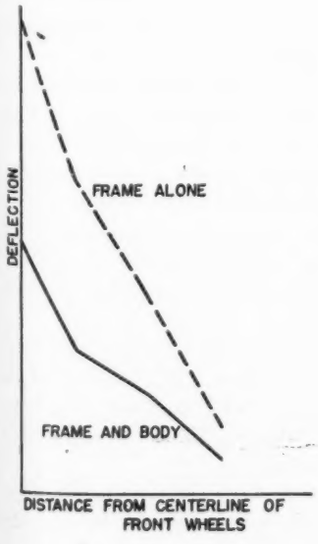


Fig. 2 — Typical torsional deflection curves obtained with the set-up shown in Fig. 1, showing strengthening effect of the body

It was then decided to investigate the vibrational and dynamic strength characteristics of experimental cars and to establish the relationship of actual car strength to apparent car strength. It is the purpose of this article to present a discussion of the tests conducted and some of the results obtained.

As the first step in this investigation, six cars were selected which had road characteristics ranging from the "jelly" type to solid-feeling type. These cars were selected regardless of make, wheelbase, frame type, etc. Strength checks were then made on these cars, with the results given in TABLE I. In the tabulation, under "road impression", the cars are listed according to their feel on the road with the first car *E* being the best, and car *B* the poorest. Likewise, under "strength tests", the cars are listed ac-

From a paper presented at the recent annual meeting of the American Society of Mechanical Engineers in New York.

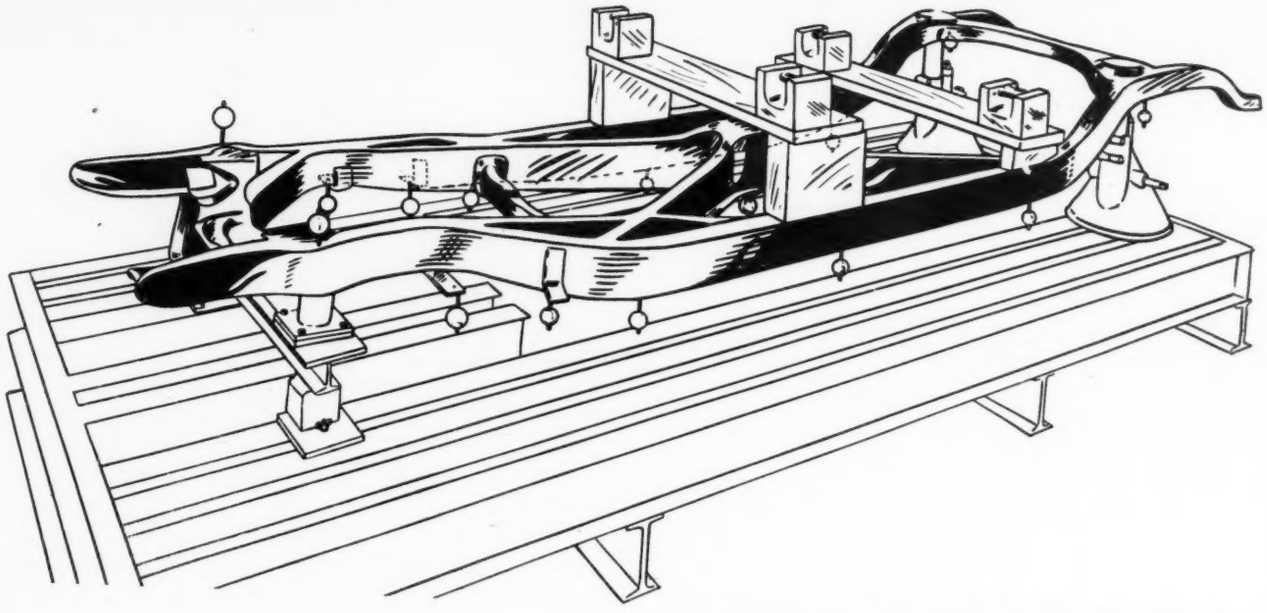


Fig. 3—Above—Loading arrangement for determining the beam strength of a passenger-car frame

cording to their strength with car *A* being the strongest and car *F* the weakest.

As will be seen from TABLE I, the feel of the cars is in almost the reverse order as compared to their strength. These data were considered of sufficient importance to warrant a full investigation.

The problem was then divided into two major classifications, namely, "static strength" and "vibrational or dynamic strength". While convinced that static strength was not the final answer to the problem, we did not feel qualified to undertake the dynamic problem until it was known which were the primary strength-contributing members, and their proportional effect on the overall strength of the car.

Test setups shown in *Figs.* 1, 3, and 5 were used. *Fig.* 1 shows the method used in testing for torsional strength.

TABLE I

Relative Strengths of Typical Cars

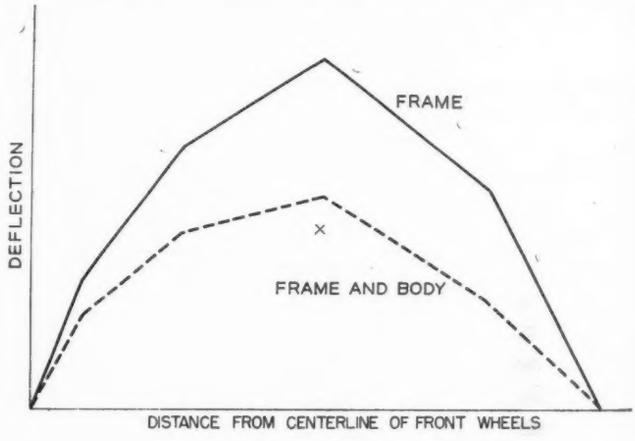
Strength Tests	Road Impression
Car *A* (Strongest)	Car *E* (Best)
Car *B*	Car *A*
Car *C*	Car *F*
Car *D*	Car *C*
Car *E*	Car *D*
Car *F* (Weakest)	Car *B* (Poorest)

The frame was held rigidly at the rear spring seats and flexibly at the front end by means of a chain on the center line of the frame. The torsional load was applied by means of the bar *A* and the weight *B*. Deflections were recorded at various points along both sides of the frame by means of dial indicators. The resulting data give a deflection curve as shown in *Fig.* 2, where the abscissa is the distance from the center line of the front wheels and the ordinate is the deflection.

Shown in *Fig.* 3 is the method of obtaining beam deflection. This test gives the curve shown in *Fig.* 4. The X shown is the deflection at the center of the X-member of the frame. No attempt was made to join the points on the curve with a smooth curve.

Method of obtaining side deflection is shown in *Fig.* 5. The frame was held at the four spring supports and loaded by means of a bell crank whose force was transmitted to

Fig. 4—Below—Curves obtained with the beam-strength fixture of Fig. 3, showing effect of the body on strength



the frame by the motor mounts. The application of the load, through the motor and motor mounts, was used because of the fact that all rear-wheel road loads are transmitted to the chassis in this manner due to the torque-tube drive. *Fig.* 6 shows the resulting curve.

The body was then installed on the frame and held in place with production body bolts and rubber shims. The three tests, namely, torsion, beam, and side deflection, were then made, the effect of the body on the over-all strength being shown in *Figs.* 2, 4, and 6. To illustrate the refinement of these tests, it can be stated that it is possible to measure the difference in the overall strength of the car when the cloth top on the convertible is up and when it is down.

It was observed that there was practically no difference in the strength of the car when the engine was installed, while rubber shims, as used in production, do not decrease materially the overall strength of the body-and-frame combination over solid-steel shims.

After completion of the static tests, attention was then turned to the dynamic or vibrational tests. As the first at-

tempt to excite the car vibrationally, the car was run on chassis rolls which had been equipped with bumps. However, it was soon learned that the problem was rather complicated and that a refresher course in Physics II was indicated. Therefore, tests were conducted on elementary spring-and-weight systems as shown in *Fig.* 7, typical results of which are indicated on the figure.

From these simple tests the various types of vibration to be encountered in the car could be recognized, and the formulas used with confidence. A car was therefore dismantled and the weights of all units and necessary spring rates obtained. This car had been driven for road impression, and static strength tests had been made on it. Hence it was felt that its characteristics were known from every angle, and that it would be possible to coordinate the data collected into terms usable in both the laboratory and on the road.

One of the first and simplest uses made of the information gained with the elementary spring-and-weight equipment was the application of the two-spring and two-weight system to the rear axle of the car, as shown in *Fig.* 8. In this application the tires and chassis springs are considered as the two springs and the axle assembly and the body-frame assembly are considered as the two weights. Road bumps are considered as the exciting force.

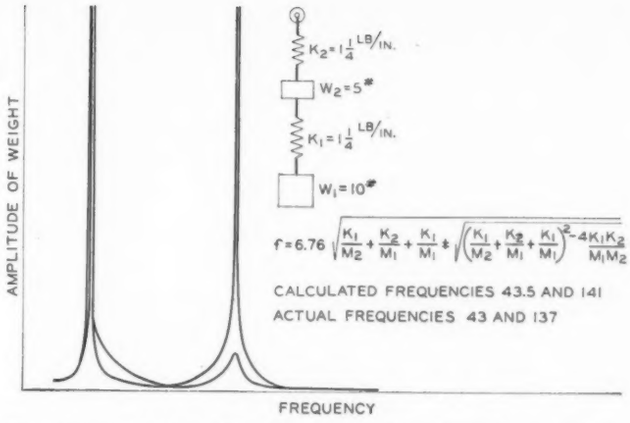


Fig. 7—Typical results of tests with the elementary spring-and-mass system shown to the right of the curves

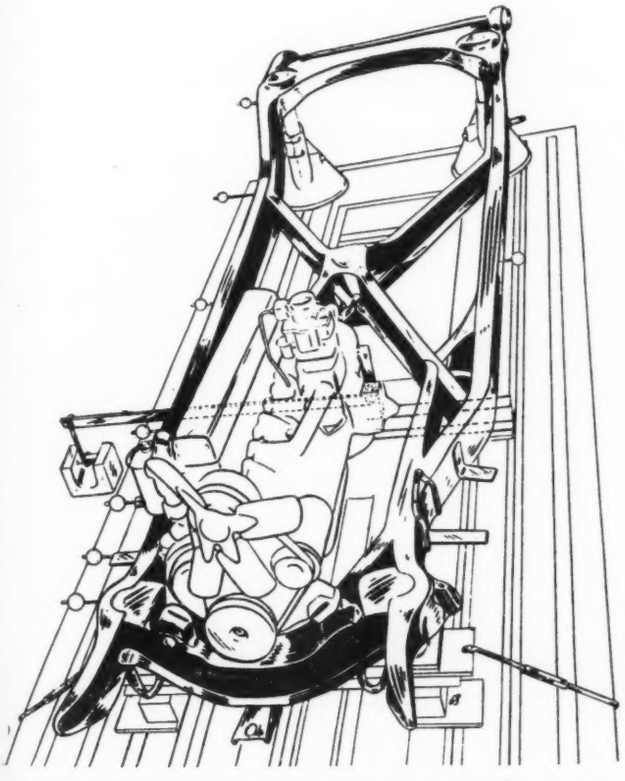
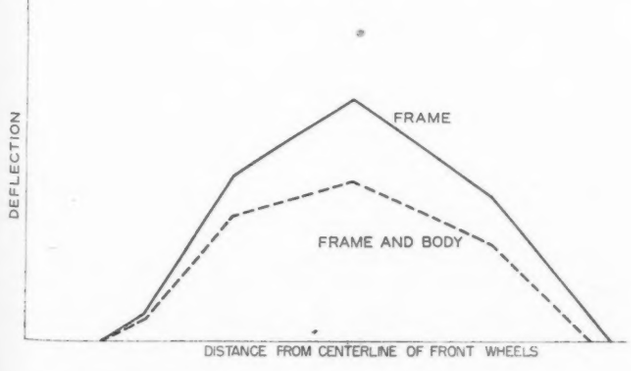


Fig. 5—Above—Method of loading the frame in determining the side-deflection rigidity

Fig. 6—Below—Curves resulting from a test with the fixture in Fig. 5 show effect of body on side deflection



In order to visualize or co-ordinate these two resonant frequencies with the action of the car, it can be roughly assumed that the 79 cycles per minute frequency is the up-down action of the car on the chassis spring, and the 535 cycles per minute frequency is the hop frequency of the wheels. In fact, the lower frequency was checked by disconnecting the shock absorbers and bobbing the car on its chassis springs. The higher frequency was checked by driving the car over a "washboard" road at a speed that produced wheel hop. Then, from the speed of the car and the number of bumps that were traversed, the frequency was calculated.

Formula Is Key to Controlling Factors

Some explanation is necessary as to why so much time was spent in calculating something that was already known. The main thought behind the calculations was to ascertain what the controlling factors were and their relative importance. To accomplish this, there is probably no better or faster method than by examining a formula that is known to be correct.

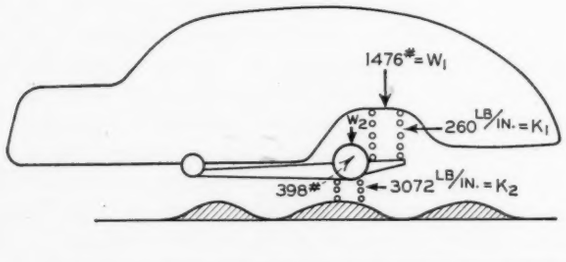
This fact can be illustrated by supposing it was desirable to lower the hop frequency of the wheels by a considerable amount. If the formula that expressed this action was not known and experimentation only relied upon, a great deal of time might be spent in testing a number of chassis springs having various rates. However, by using the mathematical approach, it was found that the frequency of the wheel hop is lowered only 15 cycles per min, or from 535 to 520 cycles per min, if the spring is entirely removed. Obviously, the chassis spring is a poor place to work.

Naturally in this work motor mountings received a great deal of consideration. Since this was to be an investigation to learn something of the importance of vibration, and since the engine contains considerable mass and is certainly suspended in such a way as to produce vibrations, the engine-mounting problem was approached without

regard to previous experience. It was decided to explore the complete range of motor-mount stiffness so, as a start, a set of all-steel mounts was made and tried. Then by steps the rate of the mounts was decreased, by adding rubber, until the fantastic static deflection of 2 in. was reached. The next step was to determine the best location for the mounts and the proper rates in the various planes in which they are called upon to function.

In vibration, two factors are involved, namely, frequency and damping. In ride work these factors are recognized and used. The springs control the frequency of the ride, while the shock absorbers and the interspring friction control the damping or amplitude of the ride. However, in motor-mounting applications most of the effort has been expended on the frequency aspect of the problem and very little on the damping phase. Until recently this approach has been both proper and correct because of the cost and the inconvenience of the method of providing the necessary friction. However it did not seem proper to ignore the possibilities of damping to help give the car the proper "feel" on the road. As a result, considerable work has been done to determine the correct amount of friction to be used in the motor mounts.

As will be recalled, if no damping is present in a vibrating system which is being excited at its resonant frequency,



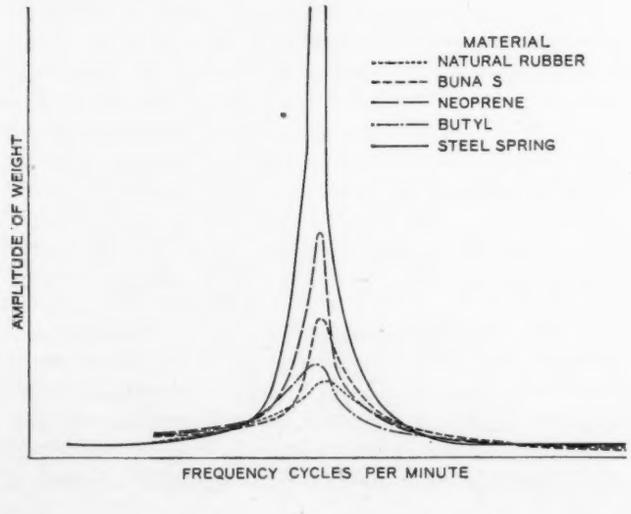
$$f = 6.76\sqrt{\frac{\frac{260}{398}}{386} + \frac{\frac{3072}{398}}{386} \quad \frac{\frac{260}{1476}}{386} + \sqrt{\left(\frac{\frac{260}{398}}{386} \quad \frac{\frac{3072}{398}}{386} \quad \frac{\frac{260}{1476}}{386}\right)^2 - 4\left(\frac{\frac{260 \times 3072}{398}}{386} \quad \frac{1476}{386}\right)}}$$

CALCULATED FREQUENCIES 76 CPM AND 544 CPM

ACTUAL FREQUENCIES 79 CPM AND 535 CPM

Fig. 8—Above—Application of the elementary spring-and-mass study to an actual passenger car

Fig. 9—Below—Damping effect of various types of materials, showing how synthetic rubbers effectively limit vibration amplitudes at the critical speed



that system will gain in amplitude of movement until some member fails. However, if damping is present in a sufficient amount, the amplitude will be controlled below the breaking point of the various parts. This is illustrated in *Fig.* 9. The solid line represents the amplitude of the weight with no friction, and the dotted lines with various amounts of friction.

In this investigation a number of types of friction were tried, as follows:

1. Dash pots
2. Shock absorbers
3. Friction devices having higher breakaway friction than running friction
4. Friction devices having equal breakaway friction and running friction
5. Rubber (synthetic) having hysteresis.

Obviously, now that synthetic rubber is available, it is the most practical method of gaining friction provided it can be controlled and does not introduce other objectionable qualities. *Fig.* 10 shows the difference in hysteresis between two identical mountings, except that one was made with natural and the other with synthetic rubber. The curves are for static side shear, and were obtained on an Olsen type of tensile machine. However, it was not certain that these curves were indicative of the true conditions encountered under actual operating conditions, since they were made at room temperature and required about 15 min for 1 cycle while, under actual conditions, 1000 cycles per min may be made.

Obtaining Data on Dynamic Behavior

To obtain data which would represent the true facts, the machine shown in *Fig.* 11 was built. This machine will test the actual mounting to be used and will give the hysteresis, temperature rise, work input, rate, and life expectancy of the mount at the frequency it is to be used. It provides for variable frequency, preload, ambient-air temperature, and stroke or amplitude, and is rugged enough to withstand continuous running called for in endurance work and production-control work.

The mounting to be tested is bolted in place at *A* and is preloaded by means of screw *B*. At point *C* a double eccentric is provided in the connecting rod so that the stroke

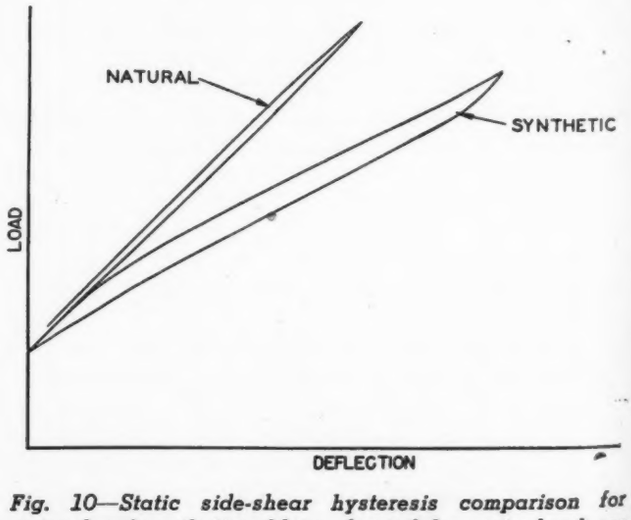


Fig. 10—Static side-shear hysteresis comparison for natural and synthetic rubbers of equal durometer hardness

may be altered. The electronically controlled variable-speed motor at *D* provides the desired frequency and will hold within plus or minus 2 rpm of the desired speed after it is once set. Ambient-air temperature is controlled either by putting the whole machine in a cold room for low temperatures or covering the mounting with a heating box for elevated temperatures. Mounting temperature is recorded by means of a thermocouple. Hysteresis is measured by means of a wire strain gage cemented to tube *E*, the electrical current being transmitted through a suitable amplifier to the oscillograph where it is recorded on a calibrated scale.

Inasmuch as hearing is the result of vibrations, if vibrations are eliminated a quiet car will be produced. Four methods are available to accomplish this objective:

1. To build a structure so rigid it will not vibrate or vibrate at a frequency so high as to be inaudible
2. To eliminate the exciting force
3. To unsynchronize the natural vibration periods of all parts
4. To absorb vibration if it occurs.

Naturally, it is physically impossible to accomplish any single one of these objectives but by working along each

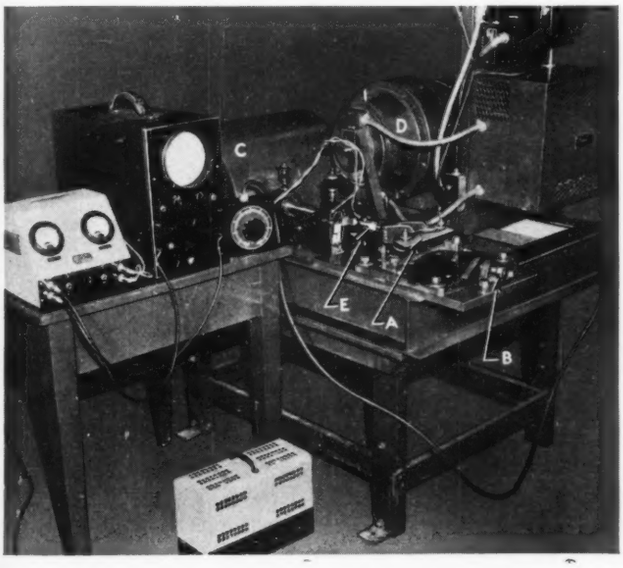


Fig. 11—Equipment employed to obtain endurance and hysteresis data on motor mountings

path until the law of diminishing returns indicates the commercial limit has been reached, a highly satisfactory noise level should be reached. One step in this direction was the development of the body shims now used in production.

Since the method used in bolting the body to the frame affects the sound qualities as well as the strength qualities of the car, a noise-reduction program was carried along as one phase of the vibration-reduction endeavor. It was established quite early in he program that the human ear is not a good instrument for measuring sound. This is due to the fact that in some cases the changes to be made were of such a nature as to involve considerable time and, since the ear does not give a permanent record, the original impression would be lost. A sound-and-vibration-level recorder was procured to give this record.

A second contributing factor to error in judgment of the

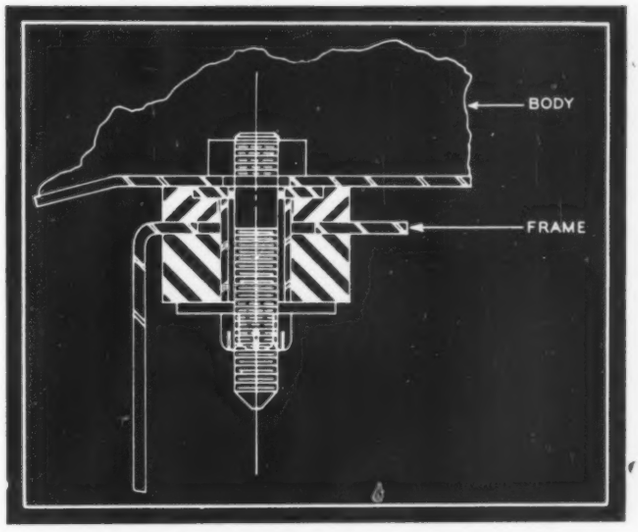


Fig. 12—Body-bolt insulation developed as a result of the study discussed in this article

noise level was the ever-changing road conditions resulting from ice, snow, etc. To obviate this, a plaster cast was made of a gravel road at the General Motors Proving Grounds where most road-noise work is done. From this pattern, cast-aluminum plates were made to fit test rolls. A set was also made to duplicate brick-road conditions.

To prove that no basic discrepancy had occurred, tests were conducted with the noise meter on the rolls and over the same road from which the casts had been made, close agreement being obtained.

With this noise equipment and strength-test data, a satisfactory type of body-bolt insulation was developed and used in production. Shown in *Fig.* 12, this type of insulation gives good noise or vibration-insulating qualities and realizes practically the full available strength of the frame and body. It also gives a predetermined preloading of the rubber and allows the body to be leveled without affecting this preload.

As a result of the investigations described in this article, a substantial weight reduction has been made in some of the frames used, and the Road Test Department reported a much better "road feel" to the cars. Also, satisfactory motor mounts were developed which completely eliminated torque reaction vibrations. Reductions of as much as 10 decibels in road noise have been made when using the equipment and suggestions outlined. The body shims developed have proved highly satisfactory in service.

Delivering in excess of 3650 combat horsepower, the Pratt & Whitney Wasp Major engine is the world's most powerful aircraft engine now in production. With 28 cylinders arranged radially in four rows, the engine has a piston displacement of 4360 cubic inches and a dry weight of 3405 lb.

Helical arrangement of the cylinders about the crankcase projects each individual cylinder into the air stream, giving excellent cooling characteristics. Other engineering improvements include elimination of conventional ignition harness through the use of seven interchangeable magnetos, one for each bank of four cylinders, and radial mounting of accessories about the accessory drive case.

Facts Behind Jet-Engine Performance

By R. P. Kroon
Manager of Engineering
Aviation Gas Turbine Div.
Westinghouse Electric Corp.

RECENT models of the first all-American designed jet engine—the Westinghouse 19B—weigh less than half a pound per pound of thrust. Like other jet engines, they may be regarded as essentially machines for increasing the speed of a mass of air, in this case some 50 tons per hour. By imparting to this amount of air a jet velocity of 1200 mph they develop a thrust of 1400 lb.

In operation, air from the atmosphere enters the circular throat of the engine—to the right of the cutaway view shown below—at the air speed of the plane, passing through a stationary ring of airfoil-shaped aluminum blades which increase its speed to about 600 mph before entering the compressor. The 6-stage axial-flow compressor has a forged aluminum rotor approximately 1½-ft long, provided with nearly 200 airfoil blades and rotating at 18,000 rpm. Air is discharged from the compressor into the combustion chamber—which looks like a perforated waste-paper-basket—where it is mixed with injected fuel and ignited. It is of interest to note that the resultant rate of heat release per cubic foot per hour is a thousand times as great as that in a central station boiler, the air particles spending only 1/100-sec in the combustion chamber.

Combustion products leave the chamber at 1500 F and pass through the blades of the single-stage turbine which drives the compressor. Of the total energy in the gases the major portion—about 3400 hp—is absorbed in the turbine, from which the gases leave at 600 mph and a pressure somewhat above that of the atmosphere. Further expansion in the 2-ft long jet nozzle increases the velocity to 1200 mph, the actual speed being controlled by an adjustable tailpiece. The air particles acquire this velocity change in only 1/700-sec, which corresponds to an acceleration of nearly 20,000g. At sea level the thrust is about 1400 lb regardless of plane speeds, hence the thrust horsepower is directly proportional to plane speed, being equal to 1400 horsepower at 375 mph.

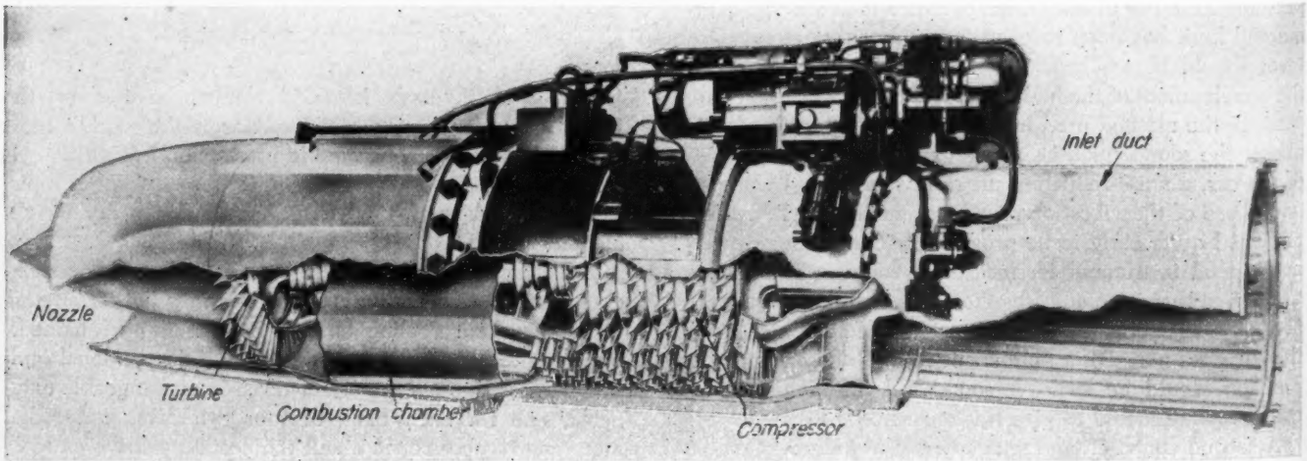
Accessories mounted on top of the engine consist of an electric starter, a fuel injection pump, a lubricating oil pump, an overspeed governor, and an electric tachometer. Other auxiliaries, which serve the airplane, include an electric generator and a hydraulic pump or a vacuum pump.

Comparing the 19B engine with corresponding German jet engines—which also are axial flow—it is interesting to note that the American engines weigh only 55 per cent as much, have 15 to 20 per cent lower fuel consumption, and have only three-quarters the diameter. With a diameter of only 19 inches, which is about half that of an equivalent reciprocating engine, the 19B presents only one-fourth as much area for drag, thus greatly reducing the power required to pull the engine and its nacelle through the air. At 500 mph the "barn door" effect in the case of a reciprocating engine may absorb as much as 30 or 40 per cent of its power.

Small Jet Engine Also Developed

A smaller engine of similar design—the 9.5A—also has been developed. Originally intended for an American "buzzless" robot bomb the unit holds promise, in a modified form, as a gas turbine drive for light planes, helicopters, cabin superchargers, and electric generators. With a top speed of 34,000 rpm the 9.5A can deliver a thrust of 275 lb yet is only 9.5 inches in diameter.

Because jet efficiency is poor at low aircraft speeds due to the high energy loss in the slipstream, use of the pure jet engine is justified only for high-speed aircraft. Furthermore, the characteristic of constant thrust—ideal at high speed—is a disadvantage at takeoff compared with the constant-horsepower propeller drive which can deliver a takeoff thrust 2 to 3 times that at maximum speed. To overcome this limitation, engines similar to the one just described but provided with a larger turbine to which will be geared a propeller will be used for moderate-speed planes.



PLASTICS Improve Design of Compass

By D. J. Faustman
Captain, Corps of Engineers
Chief, Applied Electronics Branch

WARFARE in the African desert during the initial phases of the recent war emphasized the need for a direction indicating device for use in tanks and other vehicles to provide a means for maintaining direction. For this purpose the magnetic compass was selected as the only suitable instrument for land vehicles because there was no gyrocompass sufficiently small and sturdy. Also, all of the existing types of air-driven directional gyros were vulnerable to dust and dirt.

Use of a magnetic compass in a steel vehicle presented a considerable problem in itself. Not only does the vehicle have a permanent magnetic field of its own but it also has induced magnetic fields which are dependent upon the position of the vehicle in the earth's magnetic field. Thus, large errors are introduced in the compass because of these magnetic fields.

Marine and aircraft magnetic compasses were studied for possible adaptation. Marine compasses were too large and, therefore, not considered suitable, whereas aircraft types were generally satisfactory. The problem was reduced to the development of a compensation system with sufficient strength to neutralize for the steel and iron in the vehicle and to the design of the various components capable of withstanding the violent vibrations and shocks encountered in tank operation.

Two types of vehicle compasses were produced in large quantities under Ordnanace Department direction. One is a unique design using plastics throughout, *Fig.* 1, and the other employs conventional materials and techniques used in aircraft instruments, *Fig.* 2.

Compensation of a magnetic compass was not a new problem since magnetic compasses had been used for some time on ships. Effects of the permanent magnetic field of a vehicle or ship are eliminated by introduction of permanent magnets near the compass, and the effects of induced magnetism are eliminated by appropriate disposition of soft iron about the compass. In the compass shown in *Fig.* 2, the permanent magnet corrector system is mounted above the compass and consists of two pairs of short bar magnets mounted in a horizontal plane, each pair being

Fig. 1—Produced from thermoplastics with the exception of a few small metallic parts this vehicular compass weighs less than one pound

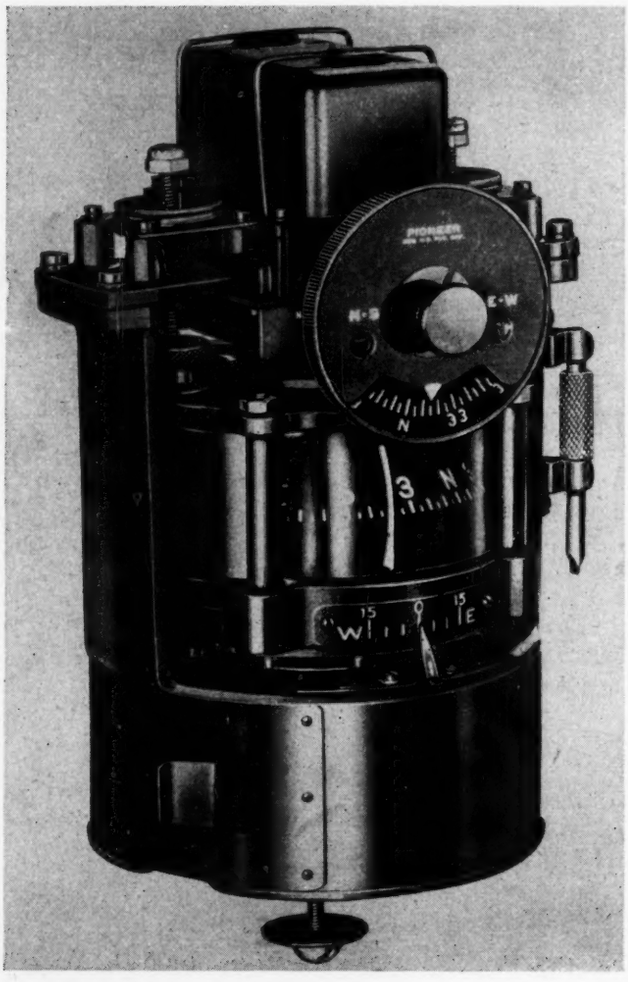
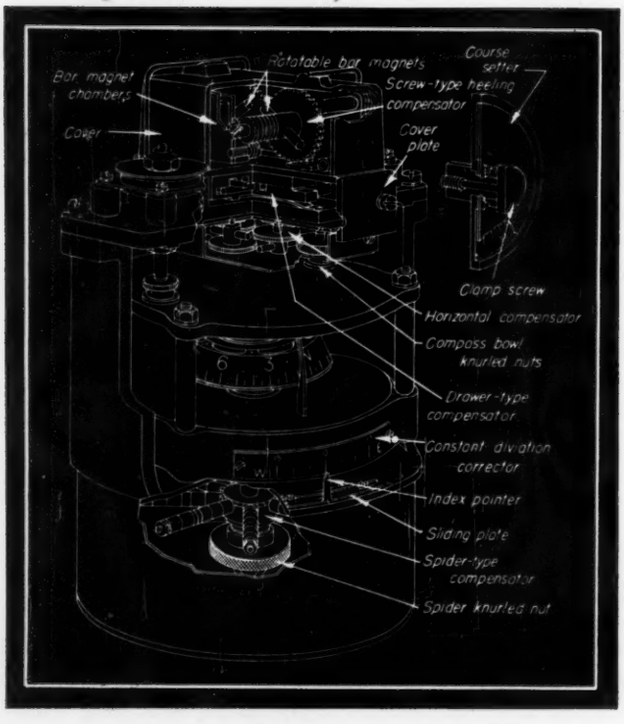


Fig. 2—Above—Three-point rubber shear-type suspension is used on fabricated aluminum compass

Fig. 3—Below—Cutaway view of vehicular compass showing compensator systems



rotated by gears. This system is illustrated in *Fig.* 3 which is a cutaway view of the compass. The two magnets making up one pair are mounted on geared shafts so that they turn in opposite directions. Thus, when the magnets are parallel a maximum correction is produced, or when the magnets are at right angles, a zero magnetic field is produced at the compass. One pair of magnets compensates for the horizontal component of the longitudinal magnetism of the vehicle and the other for the horizontal component of the transverse magnetism. A rotatable pair of magnets is placed in a vertical plane to compensate for the vertical component of the vehicle's permanent magnetic field. Correction for induced magnetism is obtained by means of permalloy rods or bars appropriately placed beneath the compass. Thus, by manipulation of the permanent magnets and the permalloy bars, the magnetic field of the vehicle can be neutralized leaving the earth's field to act upon the compass.

Limitations to Compass Effectiveness

It should be pointed out that there are several important limitations on the use of a magnetic compass in a vehicle. Cognizance must be taken of the fact that the magnetic field of a vehicle changes because of: (1) Internal changes in the magnetic structure in the steel and iron in the vehicle caused by road shocks, vibration, changes of temperature, firing of guns, etc., and (2) external changes in the vehicle such as putting the top up or down, opening doors, traversing the turret, and adding or removing metal objects such as guns.

Three general classes of external forces are found in tank operation: High-frequency engine vibrations, road shocks, and impact from large caliber projectiles. High-frequency vibrations and road shocks not only have the effect of breaking down the instrument but also of disturbing the compass card so as to make it difficult to read. If the instrument is mounted on a primary surface, a projectile impact tends to tear the equipment from the mounting. Thus the instrument becomes a secondary projectile. A conventional shear-type rubber mount adequately protects the compass from vibrations but does not protect it completely from projectile impact when mounted on primary armor surfaces. Therefore, where possible, the equipment was not installed on primary surfaces.

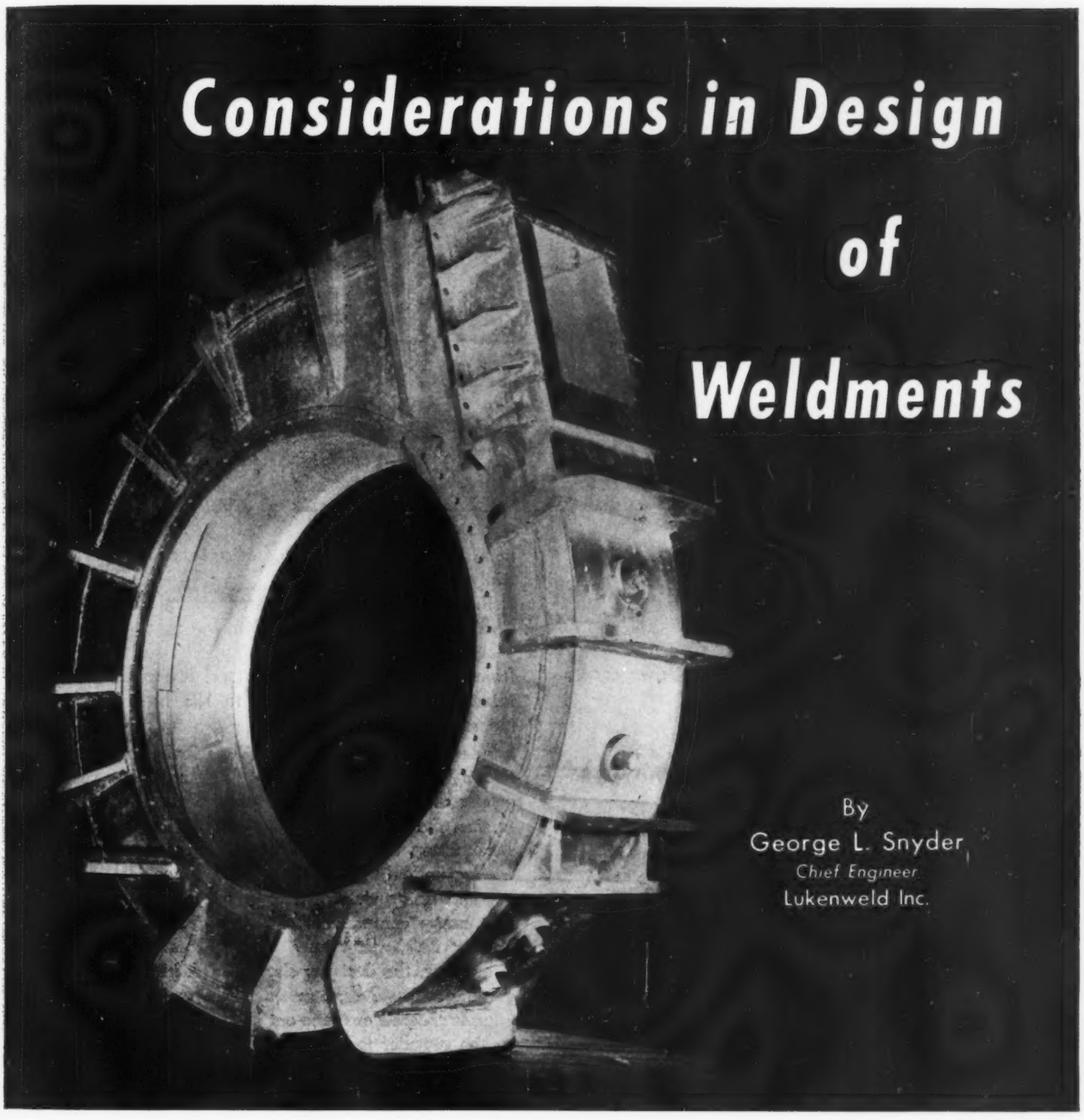
Bellows Provides for Expansion

In the compass shown in *Fig.* 2 the frame assembly is fabricated aluminum. The bowl is glass, oil filled with a special petroleum liquid designed to give stability to the compass card. Provision is made in the bowl assembly for expansion and contraction of the liquid by means of a bellows. In sealing the glass bowl, vellumoid gaskets are used. The card itself is stamped aluminum and is pivoted on a post containing a jeweled cup bearing. The compass magnets are cobalt steel containing 30 to 35 per cent cobalt. All magnets are heat treated, magnetized to saturation, and artifically aged to insure their permanance. As indicated in *Fig.* 2 a 3-point suspension system of shear-type rubber mounts is used.

The other type of compass which was finally stand-

(*Concluded on Page* 182)

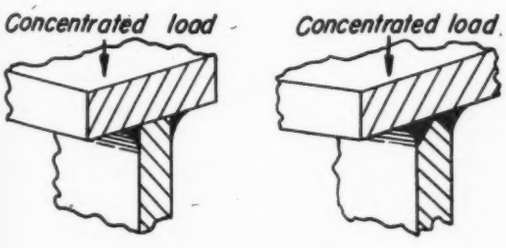
Considerations in Design of Weldments



By
George L. Snyder
Chief Engineer
Lukenweld Inc.

Fig. 1—Above—Cylindrical contours of the members of this pump casing are rolled from 4-inch hot-rolled steel

Fig. 2—Below—Machined joint between heavy flange and web, left, requires less welding than that with flame-cut joint, right



TAKEN separately, the basic considerations in the design of weldments may seem elementary and self-evident, but their complexity becomes apparent when they are considered collectively. At least twelve different types of components can be utilized by the designer of weldments, and each of these components can be used in several ways.

Limitations in processing weldments due to limitation of equipment and methods used in their production—are factors with which the designer must be familiar. These are the factors to be discussed in this article. However, this discussion is limited to dynamically loaded welded machine parts, *Fig.* 1. Statically loaded welded structures present another broad subject and their design concept is

From a paper presented at the recent annual meeting of the American Society of Mechanical Engineers in New York.

Fig. 3—Right—Comparison of metal removed in the preparation of U and V type kerfs normally used in welding

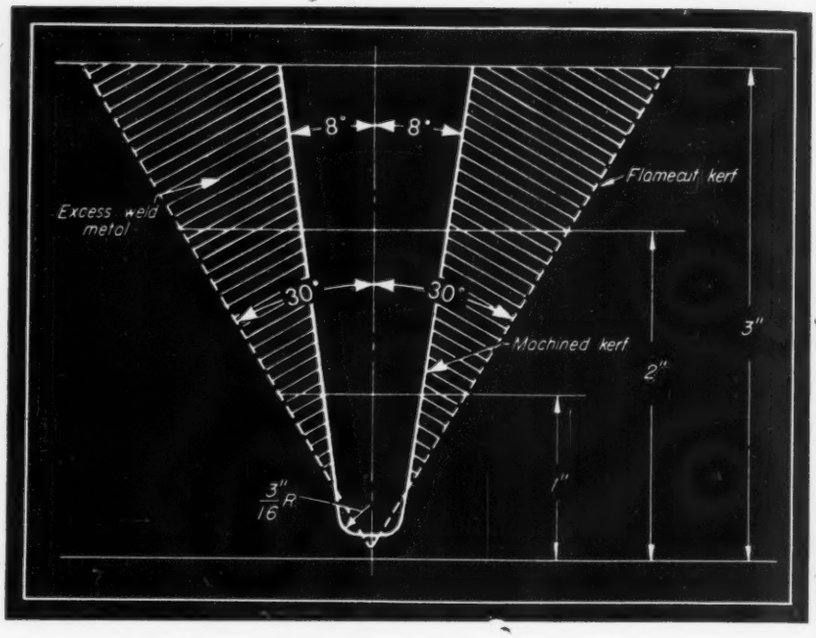


Fig. 4 — Below — Typical premachined contour and welding kerfs for heavy hydraulic cylinder subject to high working stresses

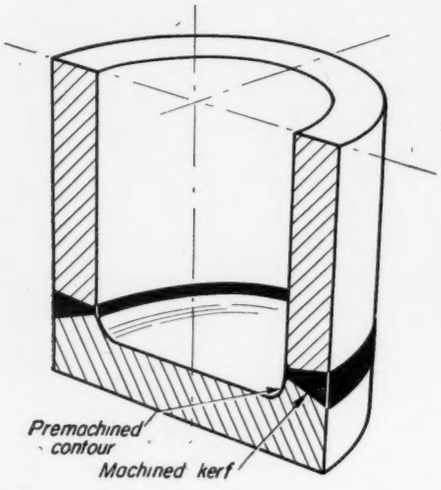
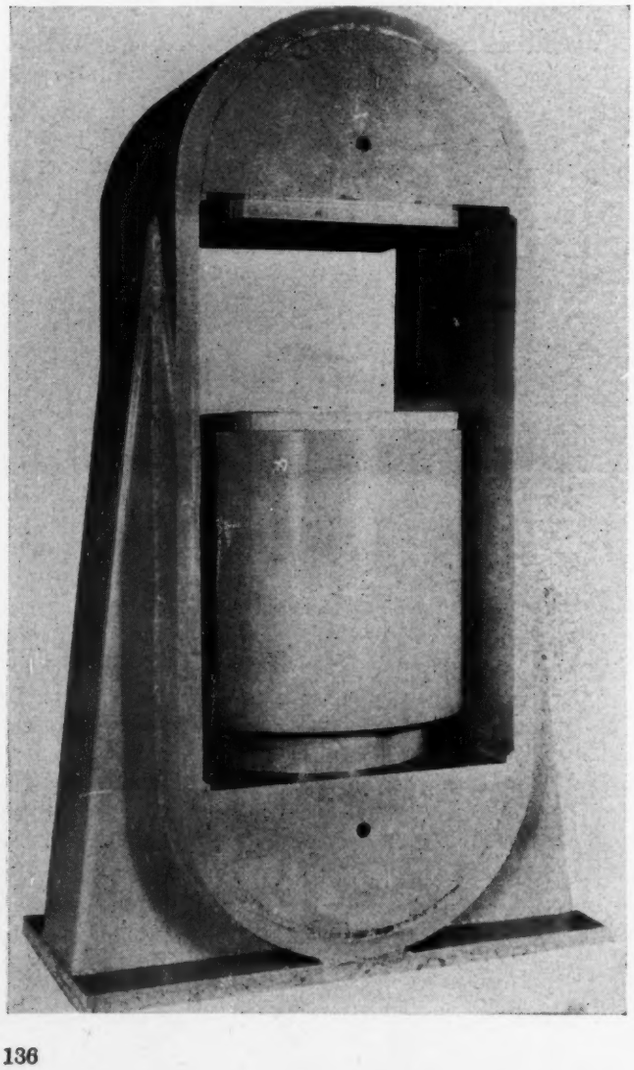


Fig. 5—Below—Hydraulic press utilizing cylinder design shown in Fig. 4



decidedly different from that of structures that are dynamically loaded.

Freedom offered by the many sizing and shaping possibilities of hot-rolled steel plate has much to do with its widespread use as weldment components. Basically flexible from the standpoint of dimensions, hot-rolled plate is obtainable in variable sizes up to 195 inches wide or 25 inches thick.

FLAT COMPONENTS: Shearing usually is the most economical method of sizing or shaping a plate to rectangular or circular dimensions. But when a plate is to be sheared to size, the designer should keep in mind the existence of shear droop that occurs along the sheared edge. Flame-cutting undoubtedly is the most common method of shaping and sizing weldment components, owning to the fact that many components of weldments necessarily are irregular in shape. Since regular configuration generally is cheaper, the designer should think in such terms where possible. However, he need not be concerned whether an edge is sheared or flame-cut as long as he designs the part so the supplier is free to use either method or both on a particular component.

Tolerances Are Important

Tolerance on components, regardless of the method used in producing them, merits careful consideration by the designer of weldments because an accumulation of tolerances can cause costly difficulty in fabrication. Tolerances are important considerations on flatness and straightness and often it is advantageous to size components on machine tools, if only for the reason that much closer tolerances are obtainable.

For a complicated assembly of parts with much welding, prefabrication machining is indicated. Also, at times, machining of components will help achieve close tolerance on a complete weldment. The more generous the tolerances on components the more prevalent the gaps in fitting. Gaps require the deposition of a greater amount of weld metal, thereby increasing costs and destroying the metal-to-metal contact which resists tendencies to shrink or warp.

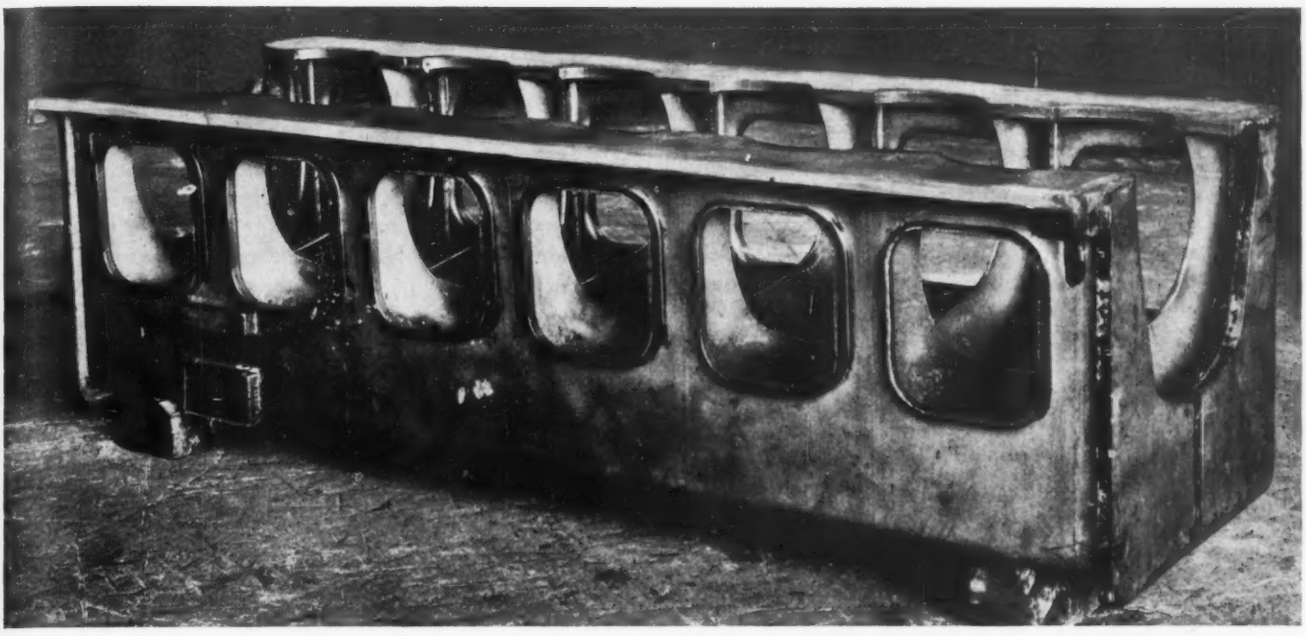
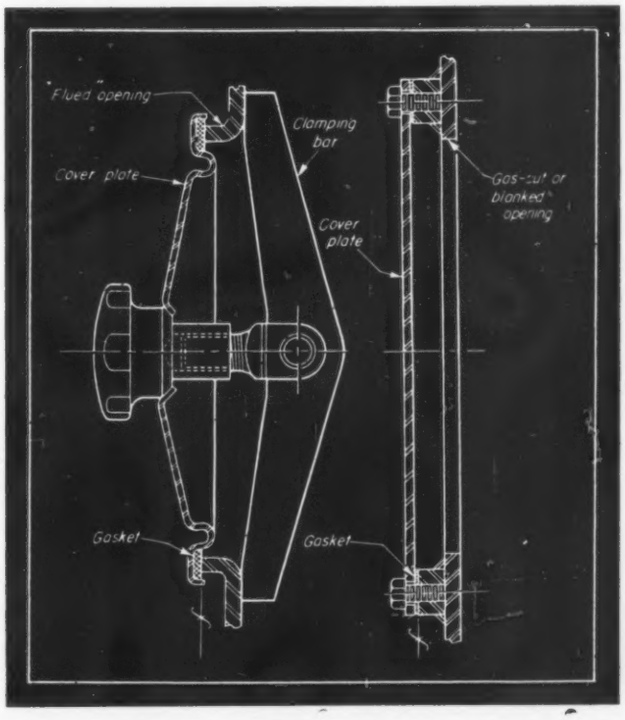


Fig. 6—Above—Flanged openings are utilized primarily to provide stiffening for large plate areas of machine bases

Fig. 7—Below—Flanged openings shown in Fig. 6, when machined, provide basis for a neat type of cover plate



Sometimes design considerations dictate prefabrication machining as in the case of the joint between the heavy web and flange shown at the left in *Fig.* 2. This is a detail of construction often found on the bed of a large hydraulic or mechanical press. The loading in the region of the compression flange is such that the joint detail shown at the right in *Fig.* 2 would be necessary if the edge of the web were not machined. When machined, metal-to-metal bearing for concentrated compression loads is achieved. Fillet welds as indicated in this illustration are adequate then for withstanding the horizontal shear components in this region of the beam.

Machined Kerfs Economical

Another reason for prefabrication machining is the provision of economical welding kerfs in combination with good joint fit-up, particularly in welding thick plates. A kerf must provide sufficient width to clear the tip of the welding electrode to permit the depositing of weld metal at the root of the weld. As the plate thickness increases, it is apparent that the amount of metal wasted in the angularity of V-shaped flame-cut kerfs in contrast to the U-shaped ones becomes an important factor, *Fig.* 3.

Prefabrication machining is necessary, too, in the fitting of circular components within each other. Studies of minimum tolerances reveal that gaps between pieces so fitted are inevitable but machined fits reduce such gaps to a negligible point. Likewise, prefabrication machining is necessary for providing proper contours in highly stressed weldments or in those subject to fatigue. In *Fig.* 4 is shown the bottom plate of a hydraulic cylinder premachined to provide proper curved contour at the corners. This sketch also illustrates an application of machined kerfs on thick plates. The cylinder of the hydraulic press shown in *Fig.* 5 is designed on such principles.

Another method used frequently for shaping plate components is "blanking" on a power press. This can be justified only when quantities required warrant the expense of dies. An important benefit gained by blanking is the uniformly close tolerance that can be achieved.

FORMED COMPONENTS: One of the several methods in general use for forming components is press bending, to make horizontal angular bends. Definite reasons for such forming operations as bending have been evolved. One is lower cost, inasmuch as angular bends eliminate one or more welded joints. The cost of bending seldom equals that of the alternative assembly and welding. Careful examination of the design proportions of metal sections might show the economy of using the same metal thickness of web and flange to utilize the advantage of a bent section. A bent component naturally is more rigid than a flat one

and can be important in the control of shrinkage and warpage.

Another method often of value is the specialized forming operation of turning out a flange around a hole sometimes known as flueing, shown in *Fig.* 6. These openings, when machined, provide seats for cover plates. Usually, such a cover is designed to be fastened by an inner clamp as shown at the left in *Fig.* 7. These openings eliminate assembly, welding and consequent warpage as well as the cost of many drilled and tapped holes required for the design shown at the right in *Fig.* 7. Primary function of flanged openings in weldments is to provide stiffening lips, which are normally made by welding a band around the opening. Since dies are necessary for flanging, such openings are unwarranted economically unless the quantity of openings is large or dies exist which can be adapted. Flanged components may provide rigidity, simpler welding conditions, or possibly a reduction in welding. When quantities justify, completely formed components or stampings may be used advantageously.

SHAPES: At times, rolling mill shapes may be used justifiably in weldments. Their value as components results from two factors, namely, a reduction in cost because of elimination of welding, and initial rigidity which tends to simplify fabrication problems of shrinkage and warpage In considering the use of rolled shapes, the tolerances possible in such rolling mill products should be studied carefully for they may affect adversely the design requirements.

Steel castings are used extensively as components in weldments where economy in producing complicated shape requirements or special contours at given points in a particular assembly is involved. When castings are to be used in weldments, their physical and chemical properties should be specified carefully. Also, where size permits, it is desirable to have castings of electric furnace steel the cleanliness of which helps in obtaining good welds.

Drop forgings also may be used when their size and quantity justify the investment in dies. Forgings have good homogeneous properties and, when properly controlled, close tolerances.

FABRICATION: Having considered the production and application of components, the subject of fabrication from the designer's viewpoint in developing a weldment is the next consideration. The first aspect covers the type and extent of available equipment. This is important since the more flexible and extensive the equipment, the more freedom there is in design. In addition, when quantities are involved, advantage may be gained in designing the job to suit particular production facilities. Usually it is well to consult with the engineering staff of the fabricator, particularly if repetitive items are contemplated.

Production methods concerning the fabrication of weldments may be considered from two aspects. The first involves the extent of what might be termed "universal" equipment, such as positioning facilities, automatic welding units, inspection methods, and stress relieving facilities. The second aspect involves special jigs or fixtures or other types of tooling that might be justified or imperative. Usually, if the product is to any degree repetitive in quantity, the possibilities in special tooling should be considered.

Also to be considered by the designer to promote economy and quality is the possibility of breaking up a weldment into subassemblies to suit positioning equipment. If the final size of a part as designed exceeds the limits of available equipment, possibly it can be redesigned so that a minimum of handling of the piece in its final size is necessary. Often the use of automatic welding equipment with its finite scope and features merits a thought in designing the weldment, especially in considering the advantage such equipment offers for cost reduction.

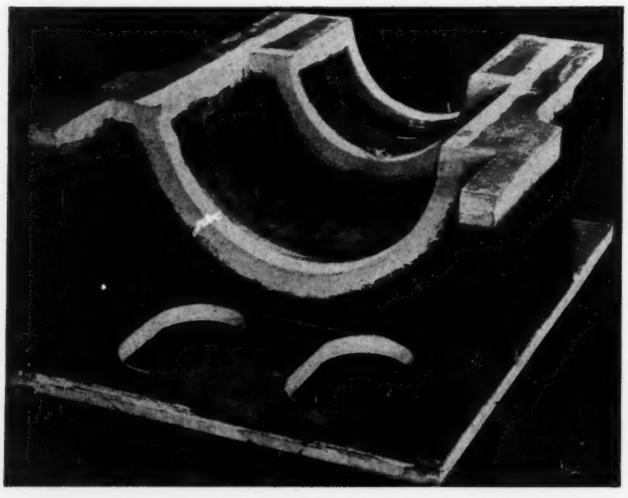
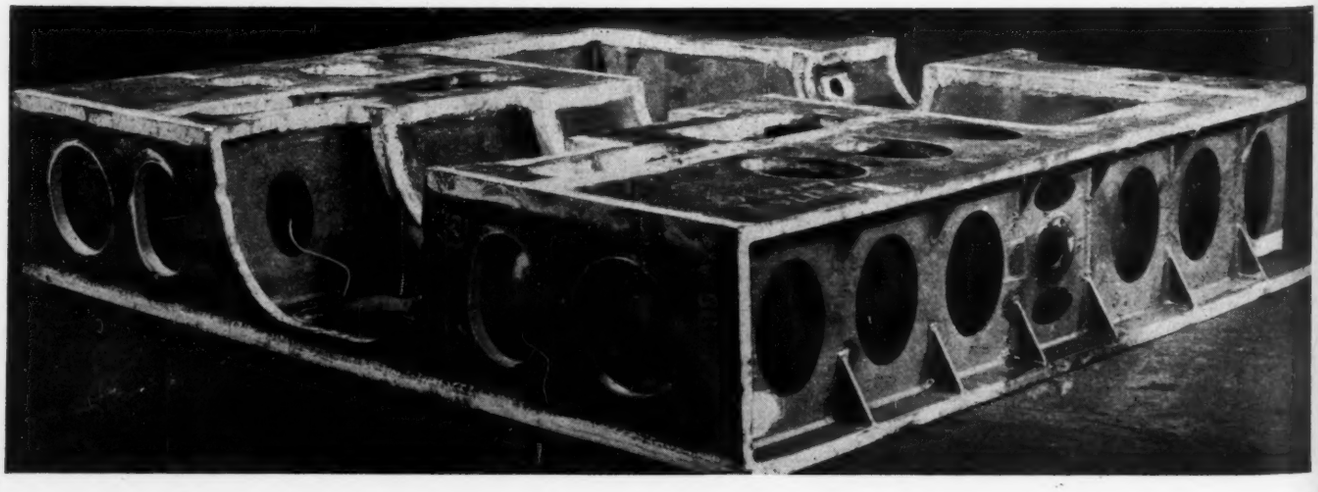


Fig. 8 — Above — A completely welded subassembly. Accessibility and easy handling are main features

Fig. 9—Below—Lower section of a welded gear reduction housing utilizing the subassembly shown in Fig. 8



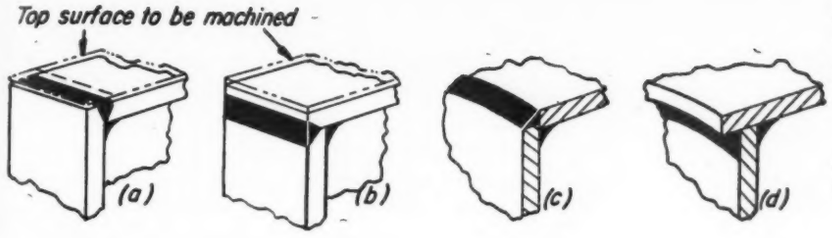
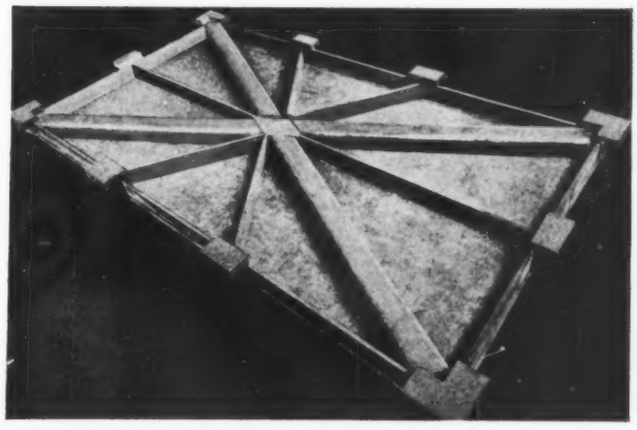


Fig. 10—Left—Joint design shown at (b) reduces weld metal necessary for similar design at (a). That at (c) eliminates kerf and (d) simplifies fitting

Fig. 11—Below—A flame-cut central member simplifies welding of the box stiffeners of this machine bed



As will be recognized the more work done on small pieces, the easier and quicker will be the completion of the final assembly. However, though subassemblies frequently are important in the design of weldments, design limitations often prohibit their use. A completely welded subassembly is shown in *Fig.* 8 and the final weldments in *Fig.* 9. Here, design controls the method of fabrication, for the lower flange member could be made in one piece. In that case, at least a portion of the subassembly welding would have been required on the larger and more cumbersome final piece.

Subassemblies of components should be made so that particular portions in certain instances can be sized before they become part of the final weldment. This practice helps insure that the final weldment is close to required dimensions. Where tolerances have accumulated, straightening or trimming might be necessary to eliminate the effect of the welding on the completed subassembly from the standpoint of warpage or shrinkage. Sometimes in complicated structures involving considerable welding, various subassemblies are stress relieved before being assembled into the whole structure to reduce the accumulation of residual stresses.

Subassemblies also facilitate inspection of welds. At times, where x-ray inspection is specified, subassembly welding is necessary for, if the welding were not completed and x-rayed in the subassembly, the interference of adjacent components in the completed assembly might make it impossible to x-ray or repair such welds.

Another important reason for careful consideration of subassembly possibilities in design is the provision of maximum access for the greatest possible amount of the welding to be done, because the more accessible the welding, the

Fig. 12—Below—Simple but effective treatment of the intersection of spokes is illustrated by the central member of this subassembly which obviates poor fitting

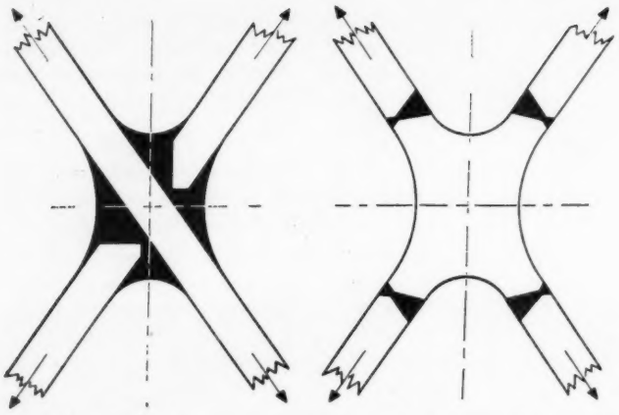
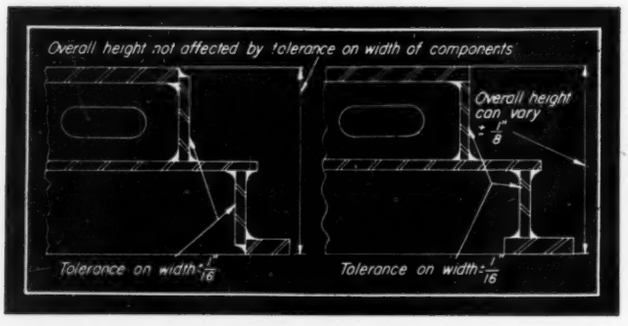


Fig. 13—Special central member of intersection, right, simplifies both welding and inspection


Overall height not affected by tolerance on width of components
Overall height can vary ± 1/8"
Tolerance on width ± 1/16
Tolerance on width ± 1/16

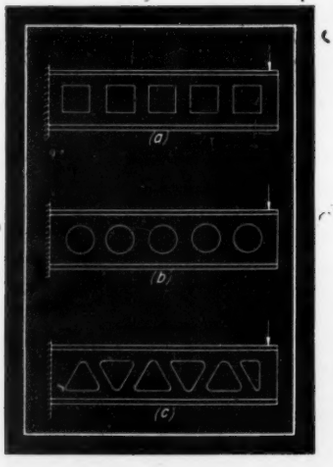


Fig. 14 — Above — Control of cumulative tolerances in assemblies

Fig. 15—Above—For a given weight, contours at (a) make component less rigid than that at (b). The most effective distribution of material is shown at (c)

less it will cost. Also, quality is more readily achieved if the welding operator can work under open or accessible conditions. At times it is advantageous to design so that progressive subassembly is possible. Thus one portion of the weldment is completed, before it is assembled and welded to other components, as a step in the final assembly of the completed weldment.

When maximum access is provided by subassembly practice or other design control, inspection is simpler and can be more conclusive. *Fig.* 9 illustrates design for accessibility with elliptically shaped openings permitting access to the inner side of the joints to be welded. Here, desirable structural qualities of a box member are not sacrificed for access, but care has been taken in shaping the openings so that abrupt discontinuities in the contour of the members are avoided. Welded joints of maximum quality and predictability from the standpoint of either external contour or internal soundness are almost impossible to execute with the manual arc if the joint is not reasonably accessible from both sides. However, at points where stresses are of secondary nature and fatigue loading is not present, joints do not require work on both sides.

In addition to the type of welded joints used, their position in the weldment deserves careful design consideration for several important reasons besides positioning for maximum access. Where machined surfaces occur in the design, care in placing joints can effect economy as comparative illustrations given in *Fig.* 10 show. Clearly, if the joint is placed as in *Fig.* 10*a*, a portion of the deposited weld metal will be removed in machining operations. Depositing weld metal is expensive and removing it is wasteful. The joint placed in *Fig.* 10*b* shows how the amount of necessary weld metal has been reduced. The joint shown need only have the cross-sectional area of that shown in *Fig.* 10*a* after it is machined. Economy may be possible by positioning a joint as shown in *Fig.* 10*c* which eliminates the kerf and its cost, or *Fig.* 10*d* which also simplifies fitting, in contrast to the same joint detailed in *Fig.* 10*a*.

At times, spoked or diagonal members are indicated by

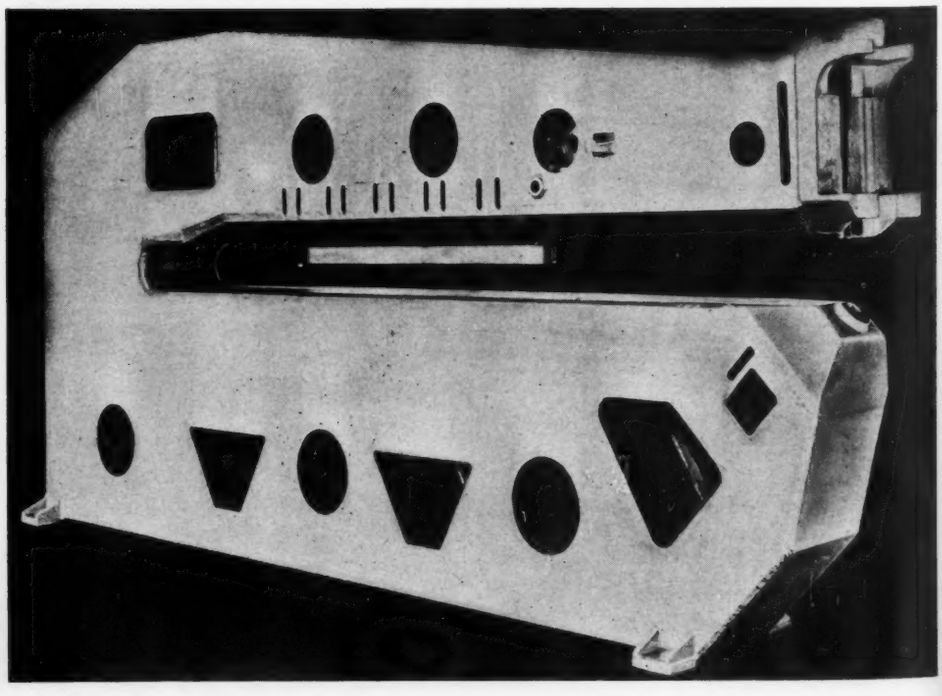


Fig. 16—Right—Circle shear frame illustrating the effective disposition of material for maximum rigidity

design considerations and their intersection usually presents a type of joint difficult to fit and costly to weld if proper external contours are to be maintained. An example is shown in *Fig.* 11. Here the diagonal pattern of the box stiffeners on the underside of this machinery bed is highly desirable from the standpoint of maximum rigidity. However, their central intersection presents a problem. By the utilization of a flame-cut central member, square joints at the intersection have been obtained; hence, fitting and welding are simplified. A simple treatment of an intersection of spokes is illustrated in *Fig.* 12. The central member in this is a subassembly so designed that the spokes do not converge on each other thus eliminating poor fitting and welding conditions.

At intersections of members subject to high stress levels, fatigue, impact, or a combination of these, careful design treatment is imperative. Contrasting designs of such an intersection of spokes is illustrated in *Fig.* 12. The central tion shows the intersection as welded without benefit of a transition member. Clearly, in order to provide curved contours, an inordinate amount of weld metal would be necessary. In addition, it is practically impossible to execute such a welded joint so that full predictable strength will result. If necessary, x-ray inspection is practically impossible. Fitting conditions are poor and the excessive amount of weld metal adds to warpage and shrinkage problems. Desirable features of a similar joint as executed in the right illustration are self-evident.

All components regardless of the method of producing them, are subject to dimensional variations. The designer must keep this in mind for economy and good fit-up so that he can control the effects of cumulative tolerances. In *Fig.* 14 is a simple illustration of cumulative tolerances. The drawing at the left shows a partial cross-section of a weldment in which the designer has kept cumulative tolerances in mind, while the drawing at the right shows a similar cross-section in which the point has been ignored.

Shrinkage and warpage problems which exist in the production of weldments will continue to be a factor so long as drastic heat gradients occur during welding. A degree of experience is needed to be able to predict such effects and to control and counteract them. It is impossible to discuss this factor here in detail. The designer should, however, sense the general aspects of such phenomena so that he does not develop designs that may be impossible to produce within necessary tolerances.

Warpage will occur to a greater or less degree depending on the relative size of given welds and their distances from the neutral axis of the assembly. This is due simply to the relative ability of a member to resist shrinkage stress imposed at different points in its cross-section with respect to the neutral axis of that cross-section.

Welding results in shrinkage both longitudinally and at right angles to the weld metal. The extent varies for sizes as well as types of welds. When the number of different sizes and types of welds occurring in an average weldment and their length and position with respect to each other are considered, it can be realized that control of warpage is to a large degree a matter of practical experience. Sequence of welding also should be carefully controlled as a counteracting measure. At times, special fixtures are used to restrain warpage during welding.

Any weldment to be subsequently machined to any ap-

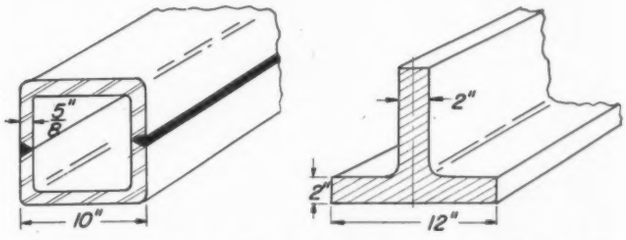


Fig. 18—Metal distribution of welded spokes, left, of part shown in Fig. 12 overcomes limitation of casting, right

Fig. 17—Below—Tubular design at bottom insures least weight in resisting a torsional force in machine members

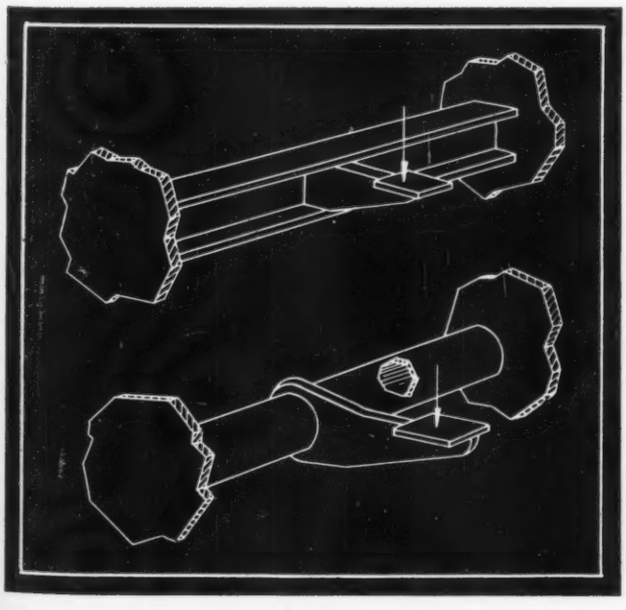
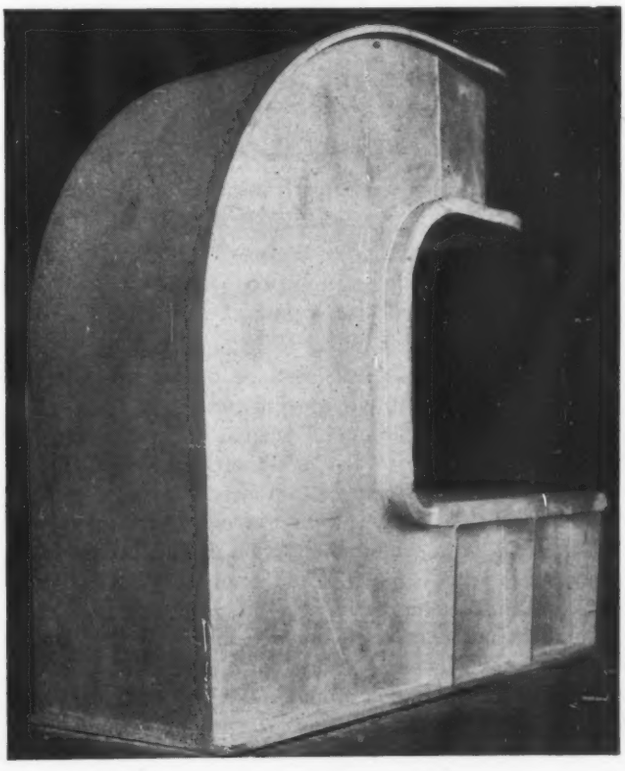


Fig. 19—Below—Material requirements, for minimum deformation at all points in this open-side press, are dictated by design



preciable degree should be stress relieved if the machined surface or other parts of the weldment are to hold their relationship within service life. Any weldment subjected to severe stresses, fatigue or impact, also should be stress relieved. Especially is this advisable since locked-up stresses, the magnitude or direction of which cannot be predicted, can be of a high order following welding. If normal service loading imposes design stresses having the same direction at a given point as that of a residual or locked-up weld stress, structural distress or failure can result. Many weldments are in use that have not been stress

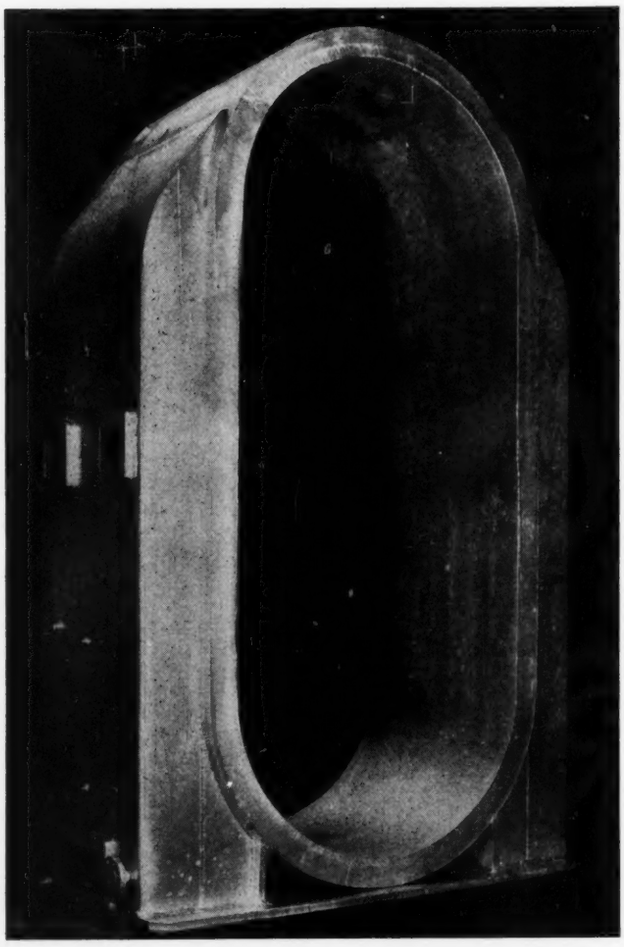


Fig. 20—Directional control of rigidity is exemplified by this welded-steel belly-band frame for a hydraulic press

relieved. Hence, definite predictions cannot be made that difficulty will result with such parts.

LOADINGS: Machine parts, as distinguished from other types of structural members, can be defined as parts required to resist or support moving forces, i.e., parts subjected to dynamic loading. Dynamic loading or applied forces in motion can involve additional factors or criteria —fatigue and impact—to be considered in the design of the part and the proper selection of material. These two factors, alone or in combination, often can affect materially or control the shape, material and manner of fabrication of a mechanical structural member.

Contours influence the effectiveness of a load-carrying member from a general standpoint. Proper contour denotes efficient disposition of material which is fundamental in control of weight. As an example, the component shown in *Fig.* 15*a* is less rigid for a given overall weight than that shown in *Fig.* 15*b*. Disposing metal as shown in *Fig.* 15*c* is more effective from this standpoint. An example of such design thought in an existing welded structure is shown in *Fig.* 16.

Internal contours—those bounding openings in a structure—are worthy of careful consideration in the design of machine parts, especially since openings of varying sizes and shapes are required for such reasons as fabricating or operating accessibility and also in certain cases for mechanical clearance.

WEIGHT CONTROL: Frequently, minimum weight is a major factor in designing machine members, and the weight of a mechanical part can be controlled by one or more considerations. Sufficient strength is the first fundamental. A minimum factor of safety is important in designing for least weight and the shape should be as regular and flowing as possible.

Another external consideration in the strength factor is the exactness of knowledge of the magnitude, direction and location of the dynamic forces with respect to each other and their reactions involved in the machine. Material resisting or supporting such forces or reactions can be disposed in a weldment to best advantage consistent with mechanical clearance requirements balanced against the necessity for least weight. As an instance, *Fig.* 17 shows an abstract example of two methods of resisting a torsional force. The effective disposition of metal in the tubular design insures least weight. Another example of effective metal disposition is shown in the spokes of an enormous machine part, *Fig.* 12, the cross-section of which is shown on the left in *Fig.* 18. The illustration on the right shows the spoke as it was designed initially, because of casting limitations.

RIGIDITY: The dominant factor in the design of structural parts for machines sometimes is rigidity, or stiffness, rather than strength. The primary function of the spokes in *Fig.* 18 is maintenance of alignment between machined parts in the structure to the greatest possible degree. Rigidity or minimum deformation dominates the design of the C-type, or open side, press frame shown in *Fig.* 19. This weldment is composed exclusively of hot-rolled plate with metal thickness at any point dictated solely by design requirements.

A welded design that embraces directional control of rigidity is shown in *Fig.* 20. Purely vertical deformation or elongation is a secondary consideration in the function of this machine. Deflections in a manner detrimental to the alignment of tools and work, are practically eliminated in this design where the single structural member resists the working forces imposed on it in direct, uniform tension.

Stabilization of thin and unsupported expanses of metal is a new element which requires watchfulness in the design of weldments for machinery. These thin and unsupported expanses of metal may be detrimental to the operation of the machine for several reasons. One is the possibility of "drumming" or vibration, another is fundamental instability, and the third is the possibility of dents or distortion in normal handling of the structure.

SIZE LIMITATION: Generally, the fewer the number of pieces bolted together to make up a machine structure, the less it will weigh and cost, and the stiffer it will be. The only limitations on the size of a weldment are those imposed by stress relieving facilities and shipping clearance.

MACHINE DESIGN

Editorial

Don't Hamstring the Patent System!

ATTEMPTS to change the United States patent system have been gaining in intensity during the past ten or fifteen years. Is it a coincidence that during the same period the number of inventions for which patent applications have been made has dropped off to the point of being, in 1944, only about half that of 1930?

This comparison is of course somewhat too direct. Other influences such as the depression and the war have affected the number of patent applications. But that attempts to "meddle" with the patent system have had a considerable bearing on the drop in applications is unquestionable.

Although there has been no primary change in the patent laws, interpretation of the laws has become more and more loose. The tendency of the courts to lean heavily toward the nonsupport of claims for which patents have been granted has diminished or nullified the value of patents and at the same time discouraged inventors in their work.

Another retarding influence is the threatened compulsory licensing of patents. Even though such procedure might be beneficial in remote instances, the general effect (as brought out by the former National Patent Planning Commission headed by Charles F. Kettering) also would be to nullify the patent owner's proprietorship and discourage inventiveness.

Many of the proponents of the proposed compulsory licensing law, and others who have attacked the patent system, have based their arguments on the cry of monopoly. It may be said, however, that the term "monopoly" can no more be applied to the right of ownership to a patent than to the right of ownership to other personal or industrial property.

With the current drastic need for continued inventiveness and subsequent disclosure through patent application, it is to be hoped that every step will be taken by the courts and by Congress to encourage research, development and invention with a view toward providing one of the basic stimulants to progress so essential at this time.

L. E. Jermy

Outstanding Designs

Automatic Piston-Ring Inspector

This machine, manufactured by The Sheffield corporation, can automatically check 1500 piston rings per hour. Operating cycle starts with a feed slide carrying the bottom ring from the stack into gaging position where the ring is compressed and gap width determined. A vertical-feed spider then descends onto the ring, pushing it into a constantly rotating master ring, and a concentrated beam of light projected through an optical system scans the outside periphery of the ring where it is in contact with the master. Any lack of light-tightness energizes a photoelectric cell that sets up a holding circuit by means of a relay through which mechanisms for either accepting or rejecting the rings are actuated.

OUTSTANDING DESIGNS SERIES

Since the beginning of the machine age, the designer's job has been to develop faster, more automatic, sturdier, more trouble-free and better looking machines. In pursuit of this overall goal, there are, for any given period, trends in mechanism design, methods of construction, materials utilization and styling. It is the purpose of this series to help engineers responsible for design to keep abreast of general trends and developments in all types and sizes of machines

Paper Shredder

Formed sheet-steel guards on top of this shredding machine made by Universal Shredder company can be lifted back on hinges to permit access to knives and drive units. Straight-edge knives are mounted on a cylinder at an angle to effect a shearing cut with the stationary knife located on the machine frame. Standard V-belts are employed to convey the paper to the knives and the conveying unit is designed so as to permit belt changing without the use of tools. Conveyor unit is a separate integral assembly which can be lifted from the machine proper by releasing pressure hooks that are held down by coil compression springs. Individual tension on the conveyor belts is provided by means of coil compression springs which exert pressure on yokes that hold idler pulleys. Conveyor is driven by a gear attached to the bottom feed roller which in turn is driven by chain from a swinging arm below. This swinging arm is designed in such manner as to permit the control of the conveyor speed through a simple crank adjustment. Completely encased mechanism reduces noise of machine to a minimum.

Fast Battery Charger

Case top of this battery charger is a single-draw, 18-gage part and base is formed of 10-gage steel. Battery clamps are heavy cast bronze designed to withstand rough use. Rotary switch employed has positive make-and-break action initiated by a ball-bearing indexing mechanism. Stationary and rotating arms of rotary switch employ silver inlay contact points to insure long life. Transformer which supplies the rectifier is vacuum impregnated and of heavy-duty design. Selenium rectifier is in base and positioned over a grill through which intake air provides cooling for the rectifier stack. A four-blade fan exhausts the air through the case back. Manufacturer is The Benwood-Linze company.

Portable Clothes Washer

Designed to wash, rinse and damp-dry clothes, this machine manufactured by Easy Washing Machine corporation incorporates die-cast aluminum alloy gearcase and high-speed gears of die-cast zinc. Bearings of spinner-basket are phosphor bronze, water lubricated, with weight of the basket load carried on a ball thrust bearing located under the oil-level in gearcase. Drive is by flat belt from motor to worm reduction unit. Drive shaft and worm are hardened and ground alloy steel, the shaft being cadmium plated for improved corrosion resistance. Bearings of drive unit, which is an integral unit assembly, are self-lubricating bronze and lubrication of gears is effected by splash system. Spinner-basket is die-cast zinc and finish on outer case or tub is white porcelain enamel.

Cooker

With body and cover of one-piece sheet aluminum, this four-quart pressure cooker, designed and manufactured by the National Pressure Cooker company, has heat-resistant plastic handles specially designed to obviate twisting. A groove is formed in the cover to retain a flat flexible gasket which effects a seal between body and cover. A small aperture is extruded in the cover to hold a pressure-release antivacuum disk. Locking lugs on the cover are formed so that only a slight rotation of the cover is required to lock the two firmly together. Entire cooker has a high luster finish which aids both styling and service.

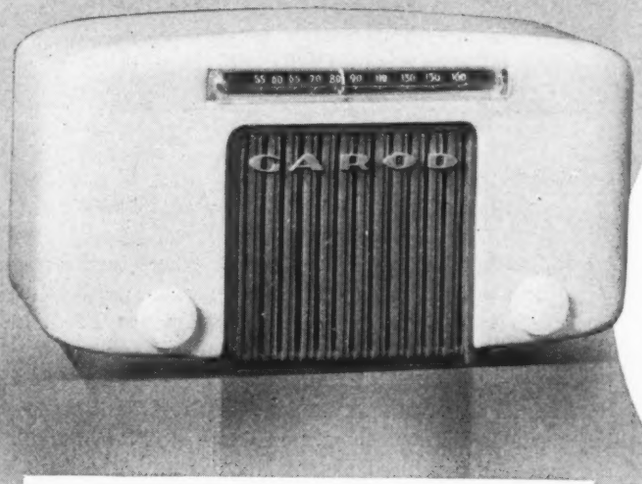
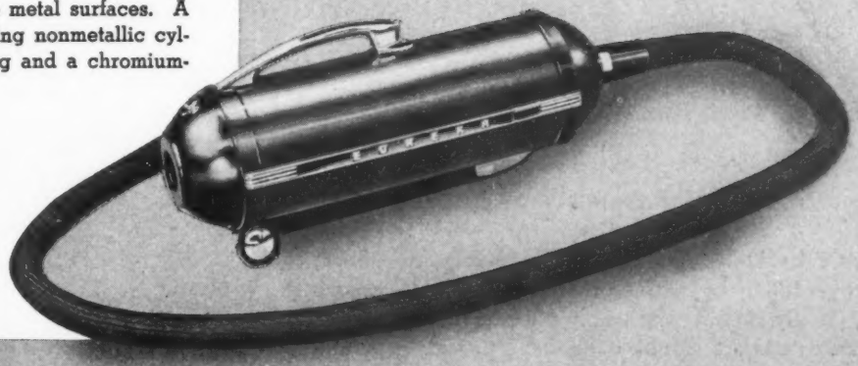


Table Radio

Various advancements first used in compact military receivers have been incorporated in this table radio manufactured by the Garod Radio corporation. Alnico "5" permanent-magnet alloy is employed in the dynamic speaker and gives a flux density more than three times that of prewar magnetic alloys. Vinylite plastic window for the slide-rule dial is tilted at 30 degrees for easy visibility from any position. The dial pointer mechanism is actuated by a cord-type drive through a large-diameter, high-ratio pulley. Cabinet is compression-molded urea and knobs are injection-molded acetate plastic.

Tank-Type Vacuum Cleaner

Cleaning suction and motor-cooling air is supplied by balanced fan assembled direct to motor shaft in this tank cleaner manufactured by Eureka Vacuum Cleaner company. Motor is mounted in rubber at both ends with no metal connections to outside metal surfaces. A sound and vibration-deadening nonmetallic cylinder is used for the housing and a chromium-plated one-piece metal handle is fastened to the housing by two screws. Chromium-plated steel side rails run full length of housing and prevent damage to the cleaner.

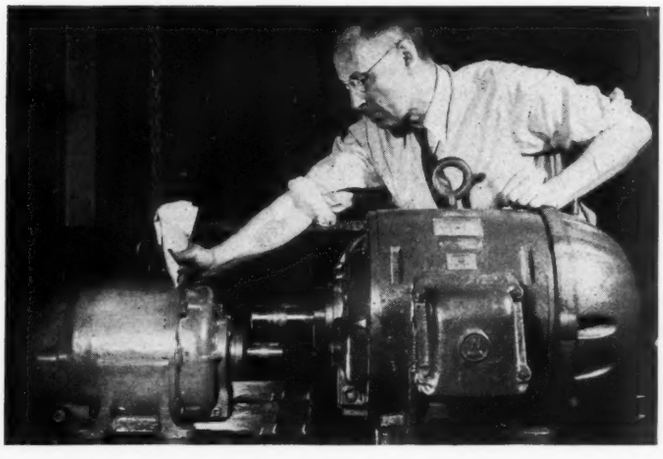


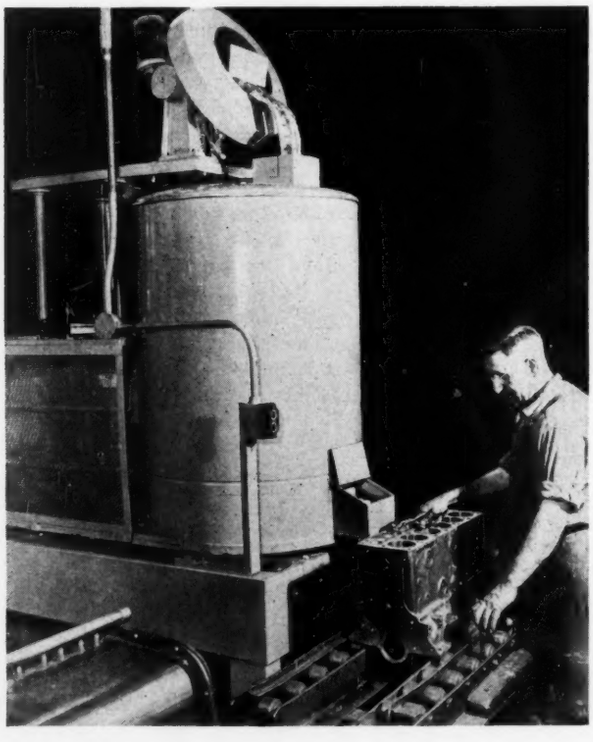
Applications

of Engineering Parts, Materials and Processes

Insulation Reduces Size

SMALLER of the two motors in the illustration, right, both designed and built by Westinghouse, is insulated with Dow Corning silicones. One-half the size and weight of the conventionally designed class-A motor shown, the silicone-insulated motor produces exactly the same power output—ten horsepower at 1750 rpm. Higher operating temperatures (175 C hot spot) make this possible and even at such temperatures the silicone insulation will outlast ordinary class-A type insulation by many years.



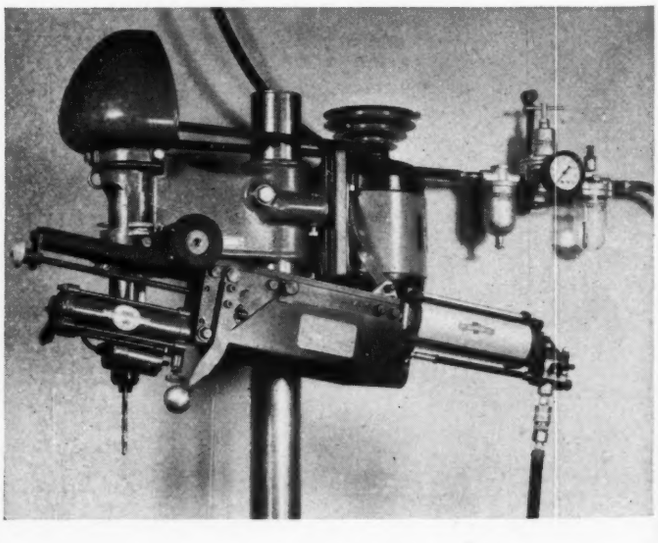


Simplifies Assembly of Inserts

PRODUCTION chilling of steel valve inserts, above, to −120 F by means of a hopper-fed Deepfreeze unit, greatly simplifies assembly into the motor cylinder blocks. Parts are shrunk 0.002-inch, providing permanent shrink-fit assemblies at 360 units per hour.

Hydraulic Feed with Air Power

AUTOMATIC "stepless-range" air power feed for use on drill presses, milling machines, surface grinders, etc., is easily obtained by means of Bellows-Senacon Feed, below. Delivering a power thrust approximately five times any line pressure up to 160 psi, the unit advances work or tools a predetermined distance and automatically returns them to starting position. Bellows-Senacon Hydro-Check, a hydraulic resistance unit, provides constant, steady feed without the usual bounce or spring normal to air power.



Charts Aid in Specifying Gear-Pin Sizes

By William T. Taylor
Part 2

CHARTS presented in Part I of this Data Sheet (M. D., December 1945, Pages 151-154) covered the selection of over-pin dimension constants for external involute gears with 14½-degree pressure angle. In this issue similar charts (*C* and *D*) are given for such gears with 20-degree pressure angle, as well as a chart (*E*) for internal gears. Equations to be used with these charts appeared in Part I, and will be referred to in the following worked examples.

EXAMPLE 3: An external odd-tooth helical gear with 13 teeth, 14½-degree pressure angle, 8 diametral pitch, 45-degree helix angle and of standard tooth proportions is to be measured with 0.2100-inch pins or balls. Determine the over-pin dimension.

SOLUTION: For helix angle $\phi'' = 45$ degrees, $1/\cos \phi'' = 1.4142$, and $1/\cos^3 \phi'' = 2.828$, therefore $N' = 13 \times 1.4142 = 18.3846$ and $N'' = 13 \times 2.828 = 36.7640$ (say 37 teeth). From Chart *B* ($\phi = 14\frac{1}{2}$ degrees), factor *k* for this value of N'' is the mean value of 36 and 38 teeth, or $k' = (0.2560 + 0.2540)/2 = 0.2550$-inch, therefore from Equation 2*a*

$$M' = \frac{k' + (N' + 2)}{P'}$$

$$= \frac{0.2550 + (18.3846 + 2)}{8} = 2.5800 \text{ inches}$$

Also, from Equation 3*a*

$$M'' = (M' - d) \cos \frac{90}{N} + d$$

$$= (2.5800 - 0.2100) \cos \frac{90}{13} + 0.2100$$

$$= 2.3700 \times 0.99271 + 0.2100 = 2.5627 \text{ inches}$$

which is the over-pin dimension for this helical gear.

EXAMPLE 4: An external even-tooth helical gear with 32 teeth, 20-degree pressure angle, 6 diametral pitch, 23-degree helix angle and cut to standard tooth proportions, is to be measured with 0.2800-inch pins or balls. Determine the over-pin dimension.

SOLUTION: For helix angle $\phi'' = 23$ degrees, $1/\cos \phi'' = 1.0864$, and $1/\cos^3 \phi'' = 1.280$, hence $N' = 32 \times 1.0864 = 34.7648$ and $N'' = 32 \times 1.280 = 40.960$ (say 41 teeth). From Chart *D* ($\phi = 20$ degrees), factor *k* for this value of N'' is the mean value for 40 and 42, or $k' = (0.2489 + 0.2479)/2 = 0.2484$-inch, hence the over-pin dimension from Equation 2*a* is

$$M' = \frac{k' + (N' + 2)}{P'}$$

$$= \frac{0.2484 + (34.7648 + 2)}{6} = 6.1688 \text{ inches}$$

EXAMPLE 5: A specification for an internal involute spur gear of standard tooth proportions gives $N = 51$, $\phi = 20$ degrees, $P = 8$, $d = 0.1800$-inch with between-pin dimension $M = 6.2054$ inches and allowable plus tolerance of 0.0008-inch. It is found that 0.1800-inch measuring pins are not available, the nearest pin size being 4.6 mm (0.1811-inch). Determine the between-pin dimensions (a) when using *the required* pins, and (b) when using *the only available* pins.

SOLUTION: (a) Pin constant for the required pin size is $dP = 0.1800 \times 8 = 1.4400$-inch, and from Chart *E*, $k = 0.6409$-inch, hence the between-pin dimension, from Equation 1*b*, is

$$M = \frac{k + (N - 2)}{P}$$

$$= \frac{0.6409 + (51 - 2)}{8} = 6.2051 \text{ inches}$$

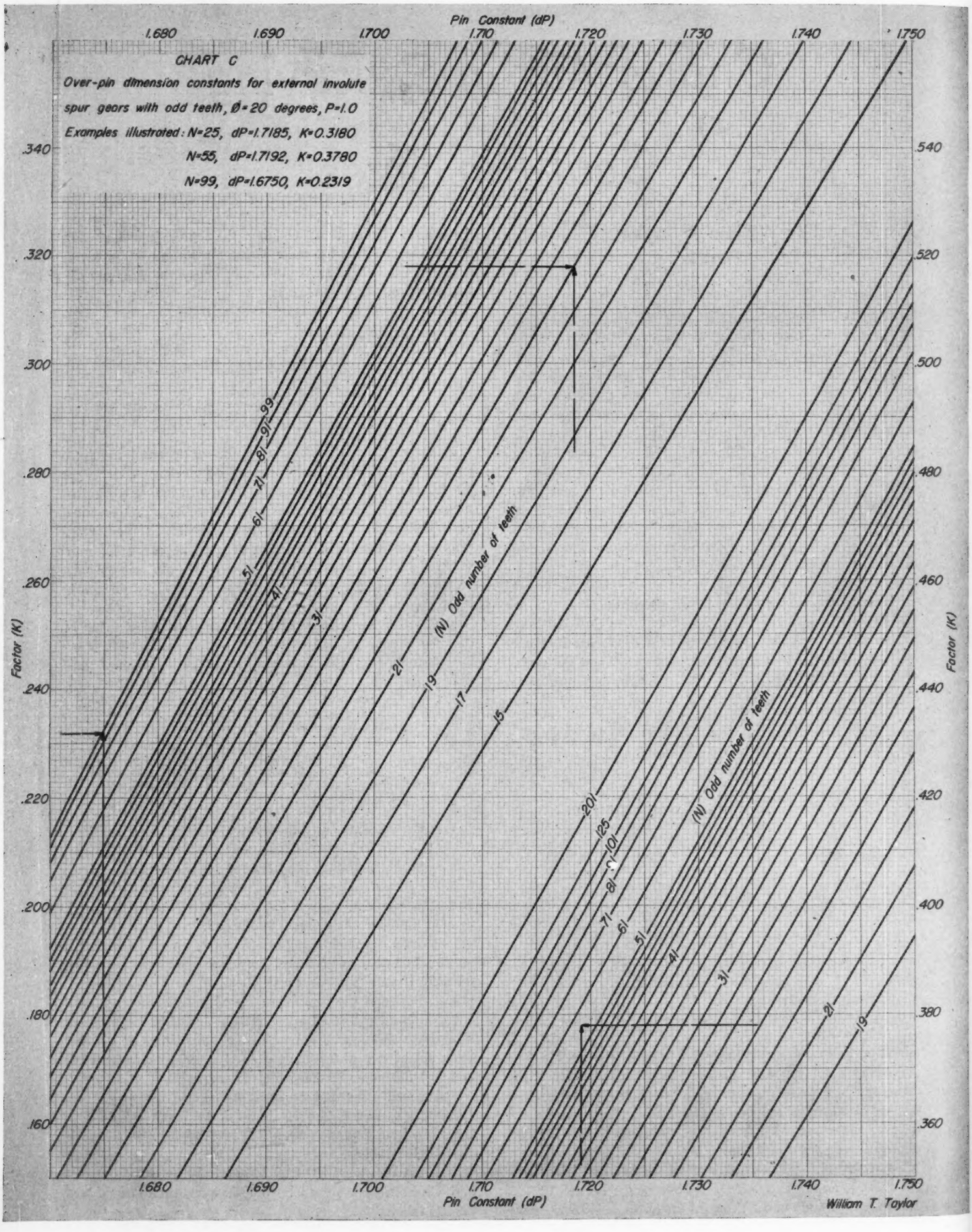
(b) Pin constant for the only available pin size is $dP = 0.1811 \times 8 = 1.4488$-inch, and from Chart *E*, $k = 0.60513$-inch, therefore the between-pin dimension is $M = 6.20064$ inches. Assuming that the *M* value for $1.4400/P$ is used in error instead of $1.4488/P$, a difference is found in *M* of 0.00446-inch plus 0.0008-inch.

EXAMPLE 6: A drawing specification for an internal involute spur gear of 31 teeth, 20-degree pressure angle, 10 diametral pitch is to be measured with pins which, when placed between the teeth, are not diametrically opposite. Two different pin sizes are available and it is required to find the between-pin dimensions when using one or the other set of two pins which are (a) 0.1500-inch diameter and (b) 3.8 mm (0.1496-inch) diameter.

SOLUTION: (a) Pin constant $dP = 0.1500 \times 10 = 1.5000$-inch, and Chart *E* shows *k* to be 0.38924-inch, therefore from Equation 1*a*, $M' = [0.38924 + (31-2)]/10 = 2.93892$ inches.

(b) Pin constant $dP = 0.1496 \times 10 = 1.4960$-inch, and Chart *E* shows *k* to be 0.4050-inch, therefore $M = 2.9405$ inches.

Engineering Data Sheet



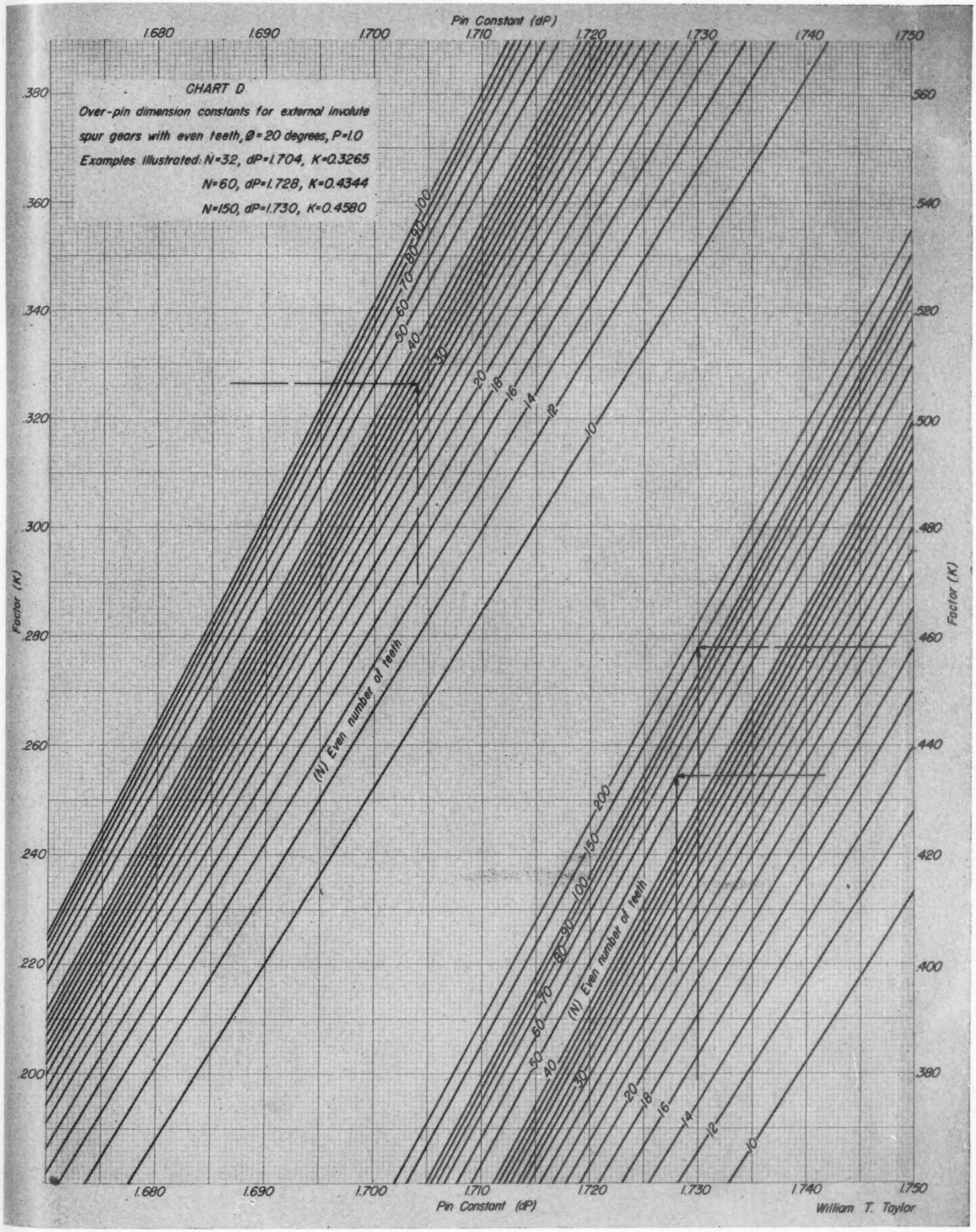
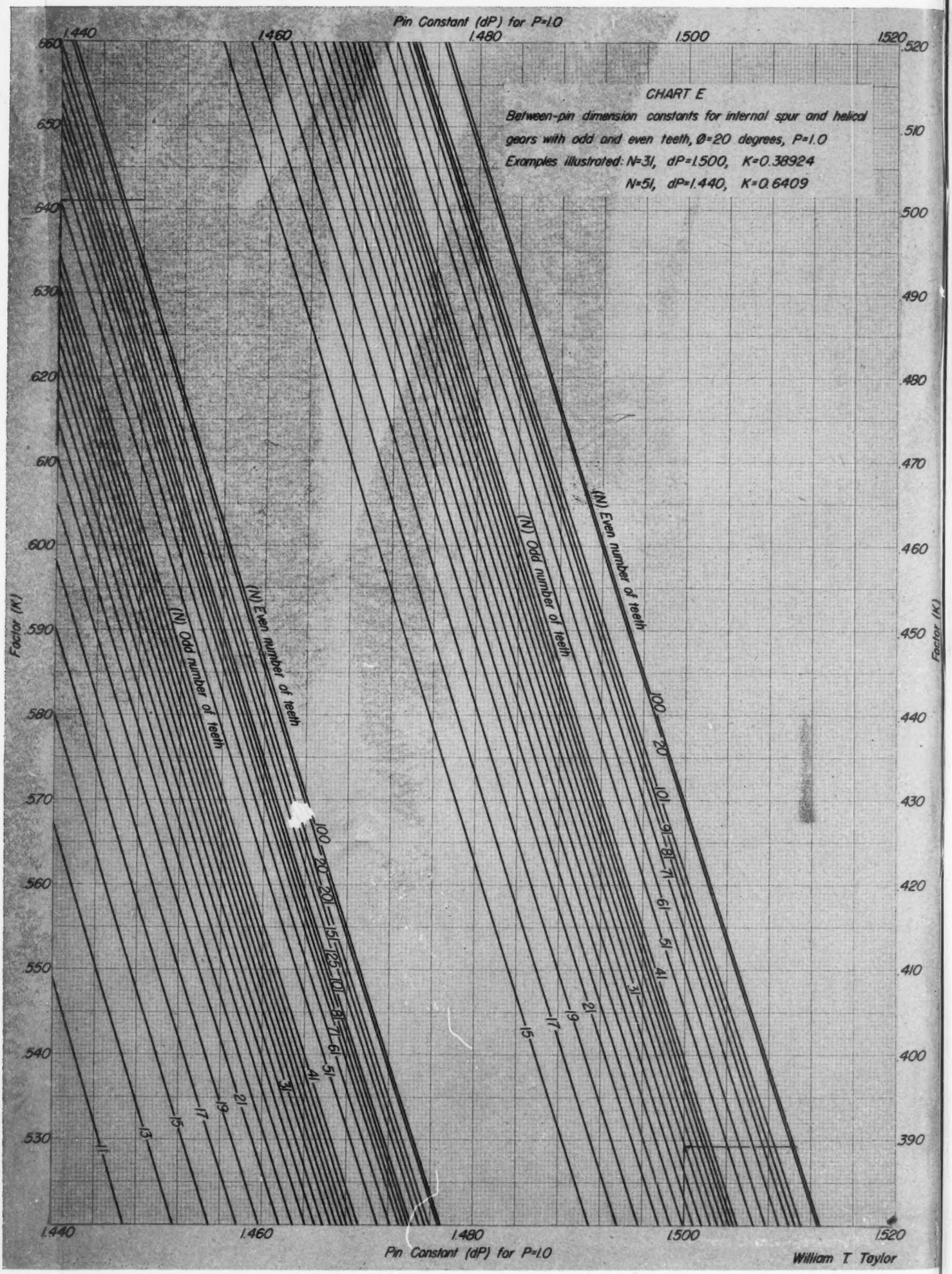


CHART D
Over-pin dimension constants for external involute spur gears with even teeth, Ø = 20 degrees, P = 1.0
Examples illustrated: N=32, dP=1.704, K=0.3265
N=60, dP=1.728, K=0.4344
N=150, dP=1.730, K=0.4580
Pin Constant (dP)
1.680
1.690
1.700
1.710
1.720
1.730
1.740
1.750
Factor (K)
.380
.360
.340
.320
.300
.280
.260
.240
.220
.200
560
540
520
500
480
460
440
420
400
380
(N) Even number of teeth
100
90
80
70
60
50
40
30
20
18
16
14
12
10
200
150
William T. Taylor


Pin Constant (dP) for P=1.0
1.440
1.460
1.480
1.500
1.520
CHART E
Between-pin dimension constants for internal spur and helical gears with odd and even teeth, Ø=20 degrees, P=1.0
Examples illustrated: N=31, dP=1.500, K=0.38924
N=51, dP=1.440, K=0.6409
Factor (K)
.660
.650
.640
.630
.620
.610
.600
.590
.580
.570
.560
.550
.540
.530
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.400
.390
(N) Even number of teeth
(N) Odd number of teeth
100
20
101
91
81
71
61
51
41
31
21
19
17
15
13
11
Pin Constant (dP) for P=1.0
William T. Taylor

MACHINE DESIGN'S

MATERIALS WORK SHEET

FILING NUMBER
7.04

Cast Steels

Vanadium, Copper and Silicon Alloy Types

ASTM SPEC. NO.: A148-44

Specifications of the American Society for Testing Materials (ASTM) for the cast steels covered in this Work Sheet fix only the *minimum* mechanical properties. Properties higher than those listed can be obtained by varying the chemical compositions and by subjecting cast parts to various heat treatments, in collaboration with a competent foundryman.

PROPERTIES PRESCRIBED IN ASTM SPECIFICATIONS*

Alloy-Steel Castings for Structural Purposes

ASTM Specification No.		Class	Heat Treatment**	Tensile Strength (min, psi)	Yield Strength (min, psi)	Elong. in 2 in. (min, %)	Red. of Area (min, %)
A148-44	(Cu type)	A1	A	75,000	40,000	24	35
A148-44	(Cu type)	A2	A	85,000	53,000	22	35
A148-44	(Cu and V types)	B1	A, N or NT	85,000	55,000	22	40
A148-44	(Cu and V types)	B2	A, N or NT	90,000	60,000	22	45
A148-44	(Cu and V types)	C1	N or QT	90,000	65,000	20	45
A148-44	(Cu type)	C2	N or QT	120,000	100,000	14	35

* Silicon cast steels most often are prepared to private specifications.
** A = Full Annealed; N = Normalized; NT = Normalized and Tempered; QT = Quenched and Tempered.

CHARACTERISTICS

Carbon-Vanadium Cast Steels: Addition of vanadium to carbon cast steel results in improved properties and considerable refinement of grain size. Fatigue-resisting properties of these steels are highly satisfactory, a typical test showing an endurance limit of 40,500 psi. They also have good resistance to impact at low temperatures, especially as compared with carbon cast steel. These steels usually are produced within the following composition range (percentages): 0.25 to 0.40 C, 0.65 to 0.90 Mn, 0.30 to 0.50 Si, and 0.15 to 0.25 V.

Copper in Cast Steels: Addition of 1 to 3 per cent copper to carbon cast steel raises its tensile and yield strength but lowers its ductility and impact resistance. Copper content of commercial cast steels rarely exceeds 2 per cent. These steels are susceptible to low tempering aging or precipitation-hardening treatment which produces an increase in tensile properties, particularly of low-carbon steels. It seems too, that copper improves the corrosion resistance of steels.

Plain Copper Cast Steels: Mechanical properties depend on total copper content, on the ratio between the dissolved and precipitated copper, and on the degree of refinement of the latter. Generally, major improvements in tensile properties result from copper additions ranging over 1 per cent. Fully annealed copper steels do not respond to precipitation-hardening treatment. Influence of copper in normalized steels is more pronounced than in the fully annealed steels. Yield strength of normalized copper steel remains high after tempering at relatively high temperatures. A wide variety of properties can be obtained in copper cast steels by varying the tempering treatment.

Copper-Manganese Cast Steels: These contain 1.0 to 1.5 per cent manganese and between 1.0 to 2.0 per cent copper and offer high strength.

Copper-Manganese-Molybdenum Cast Steels: These are high-tensile, high yield strength steels which find application in castings where weight saving is an important factor. Analyses range generally is as follows (percentages): 0.30 to 0.35 C, 0.95 to 1.25 Mn, 0.60 to 0.90 Cu, and 0.25 to 0.50 Mo.

Copper-Manganese-Titanium Cast Steels: These are high-tensile steels of low alloy content. Manganese and copper supplement each other in conferring higher tensile and

MACHINE DESIGN is pleased to acknowledge the collaboration of the Steel Founders' Society of America in this presentation. Much of the data included is based on the Society's *Steel Castings Handbook*.

yield strengths while titanium reduces the tendency to air harden and improves toughness.

Copper-Manganese-Vanadium Cast Steels: An outstanding characteristic of these steels is their excellent impact resistance after precipitation hardening.

Copper-Manganese-Silicon Cast Steels: These are the most widely used of all the various types of copper cast steels. Carbon content is kept low so that optimum ductility may be obtained for a given yield strength. While precipitation-hardening often is used, excellent properties can be achieved by annealing only. Recommended analyses range (percentages) is: 0.09 to 0.20 C, 1.50 to 1.80 Cu, 0.90 to 1.25 Mn, and 0.85 to 1.10 Si.

Copper-Silicon Cast Steels: These, like the copper-manganese-silicon steels, are of the precipitation-hardening type, but are not as widely used. The high-carbon types of copper-silicon steel (1.50 C, 1.50 to 2.00 Cu, 1.00 Si) are cast at about 2600 F and, as cast, are hard and brittle. However, by suitable heat treatment they can be made readily machinable and ductile.

Carbon-Silicon Cast Steels: Two types are being produced, their analyses ranges being (percentages): (1) 0.15 to 0.40 C, 0.50 to 1.00 Mn, 0.60 to 1.50 Si, and (2) 1.35 to 1.55 C, 0.40 to 0.60 Mn, 0.90 to 1.10 Si. It appears that silicon increases the wear resistance of steels without decreasing machinability. The low-carbon-silicon cast steels offer little if any greater strength than carbon steels at high temperatures. Also, their resistance to impact at low temperatures is not as good as plain carbon cast steel.

Silicon-Manganese Cast Steels: Silicon cast steels with additions of manganese from 1.00 to 1.25 per cent are capable of withstanding a high degree of plastic deformation and have excellent ductility. Tests have indicated that tensile strength at about 900 F runs about 60 per cent of that at room temperature. Low carbon-silicon-manganese steels are more ductile and more resistant to impact than higher carbon steels of similar strengths at both low and high temperatures.

VANADIUM CAST STEELS, NORMALIZED AND TEMPERED

(normally expected values)

Composition (%)				Heat Treatment*	Tensile Strength	Yield Point	Elong. in 2 in.	Red. of Area	Izod Impact
C	Mn	Si	V	F	(psi)	(psi)	(%)	(%)	(ft-lb)
0.22	0.82	0.37	0.20	1700 AC, 1550 AC, 1200 T	79,800	47,500	31.0	59.1	52
0.25	0.70	0.30	0.18	1725 AC, 1575 AC, 1200 T	79,000	46,250	28.0	55.0	47
0.28	0.72	0.33	0.17	1650 AC, 1225 T	85,000	55,000	28.2	49.7	..
0.30	0.69	0.37	0.18	1700 AC, 1550 AC, 1200 T	84,500	54,700	26.5	48.3	41
0.32	0.83	0.38	0.18	1650 AC, 1200 T	90,000	60,000	24.1	45.0	..
0.34	0.35	0.47	0.17	1650 AC, 1200 T	93,200	56,900	25.0	44.0	35
0.36	0.67	0.43	0.19	AC, AC, T	90,500	63,000	25.0	42.0	35
0.37	0.86	0.33	0.20	AC, AC, T	94,600	59,900	24.5	46.0	32
0.38	0.67	0.35	0.20	1650 AC, 1200 T	93,200	63,500	24.0	45.0	30
0.39	0.69	0.38	0.21	1650 AC, 1225 T	91,800	57,400	24.3	44.2	..
0.40	0.85	0.31	0.20	1650 AC, 1200 T	92,400	58,600	23.5	42.4	..

* AC = Air cooled; T = Tempered.

ENDURANCE PROPERTIES OF COPPER CAST STEEL

(0.23 C, 0.38 Si, 0.61 Mn, 1.20 Cu)

(normally expected values)

Heat Treatment* (F)	Tensile Strength (psi)	Yield Point (psi)	Elong. in 2 in. (%)	Red. of Area (%)	Charpy Impact (ft-lb)	Fatigue Limit (psi)
1650 AC	88,000	57,500	30.5	53.8	18.7	49,000
1650 AC, 930 AC	106,500	79,500	24.0	48.4	12.0	58,000

* AC = Air cooled.

COPPER CAST STEELS, NORMALIZED AND TEMPERED

(normally expected values)

Composition (%)				Heat Treatment*	Tensile Strength	Yield Point	Elong. in 2 in.	Red. of Area	Izod Impact	Brinell Hard.
C	Mn	Si	Cu	F	(psi)	(psi)	(%)	(%)	(ft-lb)	No.
0.16	0.92	0.45	1.04	1650, 1575 N	81,000	59,000	32.0	62.0	..	157
0.16	0.92	0.45	1.04	1650, 1575 N, 930 T	100,500	80,700	24.0	45.0	..	201
0.19	0.63	0.35	1.27	1650, 1575 N	86,200	64,000	28.0	50.0	..	170
0.19	0.63	0.35	1.27	1650, 1575 N, 930 T	107,750	89,250	21.5	45.0	..	223
0.24	0.65	0.35	1.26	1650 N	83,000	59,500	24.0	56.0	34	...
0.24	0.65	0.35	1.26	1650 N, 950 T	105,500	79,500	22.0	49.5	8	...
0.32	0.78	0.37	1.22	1650 N	96,500	64,500	25.0	49.7	20	...
0.32	0.78	0.37	1.22	1650 N, 930 T	116,500	84,000	20.0	43.4	..	...
0.32	0.78	0.37	1.22	1650 N, 1150 T	94,000	67,000	21.9	46.8	23	...
0.31	0.75	0.42	1.76	1650 N	114,500	86,000	19.8	42.0	..	216
0.31	0.75	0.42	1.76	1650 N, 930 T	116,500	89,500	18.8	38.8	..	215

* N = Normalized; T = Tempered.

COPPER CAST STEELS, QUENCHED AND TEMPERED

(normally expected values)

Composition (%) C	Mn	Si	Cu	Heat Treatment* (F)	Tensile Strength (psi)	Yield Point (psi)	Elong. in 2 in. (%)	Red. of Area (%)	Charpy Impact (ft-lb)	Brinell Hard. No.
0.30	0.83	0.39	1.30	1650 OQ, 1200 T	99,000	70,500	25.0	55.4	...	...
0.16	0.90	0.40	1.15	1650 AC, 1575 WQ, 1250 T	84,700	71,000	24.0	51.0	24.0	187
0.31	0.78	0.36	0.52	1600 WQ, 1200 T	98,000	69,125	26.5	57.0	34.0	183
0.31	0.75	0.42	1.21	1650 WQ, 1200 T	104,500	89,000	20.5	55.6	26.0	198
0.31	0.75	0.42	1.76	1650 WQ, 1200 T	113,000	99,000	18.8	46.9	20.5	216
0.35	0.80	0.40	0.63	1600 WQ, 1200 T	102,750	76,500	19.5	42.2	20.0	200
0.35	0.78	0.44	1.70	1600 WQ, 1200 T	114,500	102,500	19.5	42.4	17.0	221

*OQ = Oil Quenched; WQ = Water Quenched; AC = Air Cooled; T = Tempered.

COPPER CAST STEELS, FULLY ANNEALED

(normally expected values)

Composition (%) C	Mn	Si	Cu	Tensile Strength (psi)	Yield Point (psi)	Elong. in 2 in. (%)	Red. of Area (%)	Brinell Hard. No.
0.16	0.68	0.32	0.89	67,000	49,500	32.5	53.9	119
0.15	0.60	0.35	1.66	76,750	60,500	29.0	48.0	152
0.19	0.63	0.40	1.88	76,250	58,500	31.0	53.0	152
0.29	0.65	0.34	1.24	85,000	57,000	25.8	44.3	...
0.31	0.75	0.42	1.76	90,500	58,500	24.5	41.4	159
0.35	0.75	0.40	0.63	84,000	52,750	26.0	41.2	159
0.35	0.78	0.44	1.70	90,000	65,750	24.0	39.8	...
0.40	0.91	0.42	1.24	96,250	61,750	22.0	35.0	183

ELEVATED-TEMPERATURE PROPERTIES

COPPER CAST STEEL AND CARBON CAST STEEL

(test values)

(Copper Cast Steel: 0.16 C, 0.55 Mn, 0.34 Si, 0.021 S, 0.021 P, 1.06 Cu)
(Carbon Cast Steel: 0.38 C, 0.65 Mn, 0.39 Si, 0.021 S, 0.038 P, 0.15 Cu)

Steel	Properties	Temperature of Test (F) 68	212	392	572	752
Copper Cast Steel, Annealed	Tensile Strength (psi)	74,000	69,000	68,000	67,000	61,000
	Yield Point (psi)	51,000	48,000	45,000	36,000	34,000
	Yield Ratio	68.1	69.5	66.3	53.1	56.3
	Elongation (%)	22.5	22.1	17.3	15.3	18.0
	Reduction of Area (%)	51.2	46.4	39.5	31.0	20.5
Copper Cast Steel, Annealed and Tempered	Tensile Strength (psi)	88,000	81,000	83,000	80,000	66,000
	Yield Point (psi)	65,000	62,000	59,000	51,000	43,000
	Yield Ratio	74.1	75.8	71.3	63.1	65.2
	Elongation (%)	15.1	13.9	13.0	14.6	15.6
	Reduction of Area (%)	41.0	42.7	36.0	24.4	23.7
Carbon Cast Steel, Annealed	Tensile Strength (psi)	87,000	80,000	80,000	85,000	72,000
	Yield Point (psi)	44,000	41,000	37,000	35,000	31,000
	Yield Ratio	56.6	51.3	47.5	40.8	43.2
	Elongation (%)	17.6	18.5	16.3	20.3	25.8
	Reduction of Area (%)	27.6	30.5	28.0	22.0	56.0

APPLICATIONS

Carbon-Vanadium Cast Steels: Ability of these steels to support high static loads and suddenly applied overloads without rupture has been responsible for numerous and diverse engineering applications, among which are railroad, mining equipment and other heavy machinery castings.

Copper Cast Steels: Copper cast steels are being used in locomotive castings, gears, logging and excavating equipment. They are also being used for castings which cannot be liquid quenched because of their intricate design and in which a high degree of hardness is desired.

Copper-Manganese-Silicon Cast Steels: Some of the many applications are found in the logging and excavating industries for logging yarders, boom yarders, tractor bulldozers and steam shovel booms. Others are gears to be case hardened, gear-hoist housings, machine frames, cradle car castings and long shafting. Because these steels have such excellent fluidity in the molten state, they are used for many types of long rangy castings that would be difficult to run in other compositions.

Copper-Silicon Cast Steels (High Carbon): In general, these have been limited to the automotive industry wherein they are used for crankshafts, bearing sleeves, pistons, brake drums and parts that require hardening.

Copper-Chromium Cast Steels: Used for truck ring gears and parts to be carburized, also for centrifugal castings, transmission countershafts and differential ring gears for the automotive industry.

Silicon Cast Steels: Used for cams, gears, railroad track

castings subject to abrasion, and automotive and tractor castings. For high-magnetic induction applications these steels have low carbon and manganese contents.

Silicon-Manganese Cast Steels: These are used in the manufacture of cams, gears and miscellaneous castings that are subject to abrasion.

FABRICATION

MACHINABILITY:

Copper cast steels have better machinability than other alloy steels when carbon content is in the neighborhood of 0.20 per cent and casting has been normalized prior to machining. Vanadium cast steels have about the same machinability as straight carbon steels. Silicon cast steels are readily machinable, probably more so than straight carbon steels.

WELDABILITY†:

Vanadium generally is used in such small amounts that its presence is not recognized during the welding operation. Copper in amounts up to 1.00 per cent does not affect the welding operation insofar as the making of the welds is concerned. Steels containing up to 1.00 per cent silicon have been welded successfully, the silicon content producing no detrimental action during the welding operation. The best oxyacetylene welding rods contain silicon, making them of universal use for base metals with and without silicon.

†*Welding Handbook*, pages 106-107, 1942, American Welding Society, N. Y.

COPPER-MANGANESE CAST STEELS

(*normally expected values*)

Composition (%) C	Mn	Si	Cu	Heat Treatment* (F)	Tensile Strength (psi)	Yield Point (psi)	Elong. in 2 in. (%)	Red. of Area (%)	Izod Impact (ft-lb)
0.18	1.18	0.37	1.24	1650 FC	79,500	56,500	30.3	56.0	30.0
0.25	1.21	0.37	1.19	1650 FC	84,000	57,000	26.6	48.1	14.0
0.32	1.52	0.40	1.28	1650 FC	96,000	61,500	24.0	43.4	6.0
0.32	1.26	0.46	1.92	1650 FC	92,200	61,000	21.5	37.2	....
0.27	1.15	0.30	1.10	1600 AC	95,750	60,750	26.0	54.0	33.5
0.29	1.30	0.31	1.10	1600 AC	102,500	67,000	24.5	51.9	32.5
0.34	1.33	0.31	1.12	1600 AC	110,250	70,500	23.2	50.1	24.0
0.32	1.26	0.46	1.92	1650 AC, 1000 T	122,600	93,600	16.0	39.0	....
0.27	1.20	0.35	1.22	1650 AC, 900 T	104,000	71,000	22.0	45.0	20.0
0.27	1.27	0.35	1.74	1740 FC	89,500	61,700	25.0	40.0	....

*FC=Furnace Cooled; AC=Air Cooled; T=Tempered.

COPPER-MANGANESE-MOLYBDENUM CAST STEEL

(0.34 C, 1.40 Mn, 0.40 Si, 0.72 Cu, 0.31 Mo)

(*test values*)

Heat Treatment* (F)	Tensile Strength (psi)	Yield Point (psi)	Elong. in 2 in. (%)	Red. of Area (%)	Brinell Hard. No.	Charpy Impact** (ft-lb)
1700 AC, 1500 AC, 1200 T	98,750	74,000	16.0	40.4	207	46
1700 AC, 1500 WQ, 1050 T	152,000	137,500	8.5	13.1	321	28
1700 AC, 1500 WQ, 1200 T	113,250	100,000	20.0	55.2	241	53
1700 AC, 1500 WQ, 1300 T	99,000	75,500	21.0	49.7	212	62

* AC = Air cooled; WQ = Water Quenched; T = Tempered.
** Keyhole Notch.

COPPER-MANGANESE-TITANIUM CAST STEELS

(*normally expected values*)

Composition (%) C	Mn	Cu	Ti**	Heat Treatment* (F)	Tensile Strength (psi)	Yield Point (psi)	Elong. in 2 in. (%)	Red. of Area (%)	Izod Impact (ft-lb)
0.23	1.21	1.14	0.05	1600 AC, 1150 T	90,750	70,250	27.0	57.6	32.5
0.23	1.13	0.99	0.20	1600 AC	91,250	68,250	28.5	57.5	45.0
0.23	1.13	0.99	0.20	1600 AC, 750 T	91,250	68,500	28.5	56.5	44.0
0.23	1.13	0.99	0.20	1600 AC, 1050 T	100,250	78,750	25.7	52.9	24.0
0.28	1.18	1.05	0.05	1600 AC	99,000	71,500	26.7	51.4	30.5
0.28	1.18	1.05	0.05	1600 AC, 1100 T	102,000	77,750	24.7	50.1	20.0
0.28	1.18	1.05	0.05	1600 AC, 1250 T	88,750	65,750	28.7	56.3	32.0
0.31	1.12	1.00	0.05	1700 AC, 1575 AC	97,000	71,250	27.0	52.0	37.5
0.33	1.34	1.38	0.05	1600 AC	111,000	83,750	22.5	49.5	22.0

*AC=Air cooled; T=Tempered.
**Percentage titanium added.

COPPER-MANGANESE-VANADIUM CAST STEELS

(test values)

Composition (%) C	Si	Mn	Cu	V	Heat Treatment* (F)	Tensile Strength (psi)	Yield Point (psi)	Elong. in 2 in. (%)	Red. of Area (%)	Izod Impact (ft-lb)
0.29	0.44	1.12	1.04	0.10	1650 AC, 1500 AC, 750 T	96,400	73,200	30.0	57.0	61.0
0.29	0.44	1.12	1.04	0.10	1650 AC, 1500 AC, 1000 T	107,750	87,000	26.0	51.9	30.8
0.29	0.50	1.34	1.04	0.10	1650 AC, 1500 AC, 750 T	95,050	69,950	28.5	55.5	61.0
0.29	0.50	1.34	1.04	0.10	1650 AC, 1500 AC, 1000 T	106,700	85,750	24.0	48.1	30.5
0.43	0.44	1.48	0.80	0.10	1800 AC, 1550 AC, 500 T	121,200	85,800	22.0	46.3	44.5
0.16	0.26	1.43	1.15	0.11	1700 AC, 1550 AC, 750 T	90,900	69,950	30.0	60.6	76.2
0.16	0.26	1.43	1.15	0.11	1700 AC, 1550 AC, 950 T	106,150	88,150	24.0	50.6	42.0

*AC = Air Cooled; T = Tempered.

COPPER-MANGANESE-SILICON CAST STEELS

(normally expected values)

Composition (%) C	Mn	Si	Cu	Heat Treatment* (F)	Tensile Strength (psi)	Yield Point (psi)	Elong. in 2 in. (%)	Red. of Area (%)
0.10	1.19	0.84	1.27	Annealed	79,500	56,000	34.3	58.5
0.12	1.15	0.96	2.13	Annealed	83,700	64,400	34.3	58.0
0.13	1.13	0.77	1.89	Annealed	78,000	57,000	29.6	56.7
0.15	1.28	1.11	1.97	Annealed	85,800	65,000	31.2	53.3
0.17	1.18	1.12	1.80	Annealed	82,200	61,500	31.0	53.8
0.19	1.35	1.04	2.17	Annealed	86,200	63,500	31.2	56.5
0.23	1.11	1.58	1.51	Annealed	92,200	69,200	29.6	44.2
0.14	1.58	1.08	1.83	Annealed	90,000	68,000	26.5	51.4
0.14	1.58	1.08	1.83	Annealed, 975 T	92,000	77,500	29.6	57.0
0.23	1.31	0.89	1.83	1650 AC	95,500	71,500	18.7	26.4
0.11	1.04	1.23	1.74	1740 FC	81,400	64,100	31.2	55.9
0.11	1.04	1.23	1.74	1740 FC, 1580 AC, 915 T	106,750	88,500	25.0	53.3

* AC = Air Cooled; FC = Furnace Cooled; T = Tempered.

EFFECTS OF HEAT TREATMENTS ON COPPER-MANGANESE-SILICON CAST STEEL

(0.16 C, 0.95 Mn, 0.90 Si, 1.60 Cu)

Heat Treatment (F)	Tensile Strength (psi)	Yield Point (psi)	Elong. in 2 in. (%)	Red. of Area (%)	Brinell Hard. No.
As Cast	70,000	55,000	30	45	150
Annealed	88,000	66,000	28	50	160
Annealed, Precipitation Hardened at 950	92,000	77,000	27	48	185
Oil Quenched and Tempered, 800	115,000	95,000	25	45	240
Water Quenched and Tempered at 800	125,000	108,000	20	40	268

COPPER-CHROMIUM CAST STEELS

(normally expected values)

Composition (% C	Mn	Cu	Cr	Ti*	Heat Treatment** (F)	Tensile Strength (psi)	Yield Point (psi)	Elong. in 2 in. (%)	Red. of Area (%)	Izod Impact (ft-lb)
0.26	0.64	1.29	0.47	...	1700 AC, 1500 AC, 1200 T	84,500	59,000	28.8	59.4	52.0
0.26	0.79	1.27	1.02	...	1700 AC, 1600 AC	122,250	82,750	18.0	48.0	13.0
0.26	0.79	1.27	1.02	...	1700 AC, 1600 AC, 1200 T	102,100	62,800	24.0	62.0	38.0
0.32	0.80	1.20	0.53	0.10	1700 AC, 1600 AC	105,200	72,900	24.0	54.0	39.0
0.29	0.76	1.15	0.77	0.10	1700 AC, 1575 AC	103,750	76,000	25.0	52.2	17.0
0.29	0.76	1.15	0.77	0.10	1700 AC, 1575 AC, 1050 T	118,000	83,250	21.7	49.3	13.0
0.29	0.79	1.14	0.76	0.05	1700 AC, 1575 AC	105,250	72,000	24.0	54.7	9.7

*Percentage of Titanium added. **AC = Air Cooled; T = Tempered.

HEAT TREATMENTS

Vanadium alloy cast steels generally are normalized and tempered or double normalized and tempered. They may be used in the quenched and tempered condition, but normally vanadium is used in conjunction with two or three other alloys when employed for quenched and tempered castings. Copper cast steels usually are normalized, although for certain applications where low carbon contents are used, they are normalized and tempered (precipitation-hardened). Fully annealed copper steels do not respond to precipitation-hardening treatment. Silicon cast steels gen-

erally are used in the annealed or normalized state.

RESISTANCE TO CORROSION§

Resistance of steel to atmospheric corrosion increases rapidly up to 0.25 per cent copper and then more slowly for higher percentages. Resistance to corrosion continues to increase above 0.50 per cent copper only if the copper is retained in solid solution in the ferrite. Presence of 1 to 2 per cent copper in corrosion resistant chromium steels increases the resistance to atmospheric and salt water corrosion and to attack by certain acids. The influence, however, is not great and few of the corrosion resistant steels contain copper.

§*ASM Metals Handbook*, 1939, pp. 557-560.

Numerous exposure tests have indicated that painted and galvanized surfaces are more durable on copper-bearing than on noncopper-bearing steels.

MATERIAL SPECIFICATIONS

Other standard specifications covering the cast steels dealt with in this Work Sheet, in addition to the ASTM Spec. Nos. listed on the first page are, for vanadium cast steels: Federal Spec. QQ-S-681b, grades 4B1, 4B2 and 4C1; AAR (Association of American Railroads) Spec. No. M-204-39, H.T. class; and Navy Spec. 49S1, grade F. For copper cast steels the Federal Spec. is QQ-S-681b, grades 3, 4A1, 4A2, 4B1, 4B2, 4C1 and 4C2.

SILICON CAST STEELS

(*test values*)

Composition (%) C	Mn	Si	Heat Treatment (F)	Tensile Strength (psi)	Yield Point (psi)	Elong. in 2 in. (%)	Red. of Area (%)
			As cast	60,000	41,800	31.0	56
0.09	0.66	1.01	Normalized 1830	68,000	45,500	31.0	63
			Full annealed 1830	65,000	42,200	33.2	60
			As cast	65,000	34,700	25.0	48
0.14	0.71	1.04	Normalized 1830	67,500	48,000	26.0	58
			Full annealed 1830	67,900	43,900	32.0	58
			As cast	69,000	.....	21.6	37
0.19	0.66	0.99	Normalized 1830	74,400	46,100	15.5	..
			Full annealed 1830	71,200	44,100	26.6	..

SILICON-MANGANESE CAST STEELS

(*normally expected values*)

(normalized 1 hr at 1650 F, tempered 1 hr at 1250 to 1300 F)

Composition (%) C	Mn	Si	Tensile Strength (psi)	Yield Point (psi)	Elong. in 2 in. (%)	Red. of Area (%)
0.29	1.22	0.38	72,500	40,000	32.0	56.0
0.26	1.14	0.62	76,625	40,900	32.0	55.2
0.29	1.20	0.74	79,750	43,575	29.0	49.2
0.28	1.18	0.81	80,375	45,950	30.0	53.0
0.28	1.19	0.88	79,350	47,050	31.0	54.9
0.26	1.15	0.94	87,525	52,450	28.0	40.4
0.27	1.26	1.04	94,575	55,350	22.5	30.2

COPPER-SILICON CAST STEELS, LOW AND MEDIUM-CARBON TYPES

(*normally expected values*)

Composition (%) C	Mn	Si	Cu	Heat Treatment* (F)	Tensile Strength (psi)	Yield Point (psi)	Elong. in 2 in. (%)	Red. of Area (%)	Charpy** Impact (ft-lb)	Brinell Hard. No.
0.15	0.65	0.76	1.32	1750 AC	81,000	67,000	29.7	51.4	27	151
0.15	0.65	0.76	1.32	1750 AC, 840 T	94,000	81,000	24.7	44.8	18	179
0.15	0.65	0.94	1.32	1750 AC	82,000	68,000	31.2	52.3	28	152
0.15	0.65	0.94	1.32	1750 AC, 840 T	96,000	79,000	27.5	51.9	18	176
0.17	0.67	1.05	1.25	1700 AC, 1600 AC, 1200 T	80,000	64,000	32.3	64.3	..	...
0.13	0.53	1.02	1.24	1750 AC	79,000	71,000	22.5	...	..	...
0.22	0.56	0.61	1.16	1750 AC	82,000	61,000	30.5	55.0	23	150
0.22	0.56	0.61	1.16	1750 AC, 840 T	90,500	70,500	27.7	49.5	20	166
0.30	0.89	1.14	1.16	1750 AC	99,000	72,000	26.0	48.0	17	184
0.30	0.89	1.14	1.16	1750 AC, 840 T	109,000	84,000	23.0	38.8	9	197

*AC=Air Cooled; T=Tempered.
**Keyhole Notch.

ASSETS to a BOOKCASE

What Steel Shall I Use?

By Gordon T. Williams, metallurgist, Deere & Co.; published by the American Society for Metals, Cleveland; 207 pages, 6 by 8 7/8 inches, clothbound, available through MACHINE DESIGN, *$3.50 postpaid.*

Selection of the proper steel for a machine part which satisfies the strength requirements and processing limitations with a reasonable cost economy still remains a primary problem in design. This book has been written to aid the machine designer in his selection of a steel and enable him to obtain the greatest advantage possible through efficient usage.

A broad, practical guide to the selection of steels, this book covers the various steels available, their strength-weight factors, tensile strengths, work hardening characteristics, ductility, and relations to design in general of each of these important properties. Full details are presented on the evaluation of impact and hardness tests, effects of tensile properties and endurance limit on selection, wear testing, application of test results, metallurgical factors, effect of heat treatments, and influence of available equipment in the heat treating departments. A great many service failures are studied to emphasize the results of various mechanical and metallurgical conditions. Throughout the discussion the process of selecting a steel is illustrated by specific applications to the problems encountered in industry.

Judicious selection and use of steels and steel alloys will undoubtedly have a greater effect on new designs than heretofore, especially in the field of competition with the lighter nonferrous alloys. The straightforward interpretation of some of the major factors involved as outlined by the author will help greatly to clear up a vast number of the problems which daily confront the designer.

□ □ □

Procedure Handbook of Arc Welding

Published by the Lincoln Electric Co., Cleveland; 1267 pages, 5¾ by 8½ inches, semiflexible simulated leatherbound; available through MACHINE DESIGN, *$1.50 postpaid.*

Completely revised to include the latest data on arc welding methods, equipment and techniques developed and perfected during the years of war, the eighth edition of this familiar handbook obsoletes much of the material contained in the previous editions. Of the vast amount of information pertinent to the science and practice of arc welding contained in the various sections, that found in part VI on welded construction in machine design will probably have greatest appeal to designers. Covering some 226 pages, this section presents the advantages in designing for welded construction, factors affecting design, styling, materials, etc. Many drawings and photographs of machine parts are used to point up the design discussion and present a picture analysis of the design approach.

In addition to standard data on welding symbols, characteristics of metals, preheating, stress relieving, etc., many new subjects have been included such as costs, techniques, mathematical calculations for design, and underwater cutting. Representing the work of hundreds of manufacturers, the multitude of weldments and welded equipment design illustrated throughout the book help greatly to give the designer an excellent background for economical and efficient application of the welding process.

□ □ □

ASTM Standards on Plastics

Published by the American Society for Testing Materials, Philadelphia; 532 pages, 6 by 9 inches, paperbound; available through MACHINE DESIGN, *$2.75 postpaid.*

Containing the most recently developed specifications for and methods of testing plastics, this greatly amplified third edition of the handbook provides in convenient form more than one-hundred specifications and tests. Committees involved in the development of these standards are representative of both producers and consumers of the plastics materials under discussion.

Thirty-three methods of test, twenty-three specifications, five recommended practices, and descriptive nomenclature prepared by Committee D-20 on Plastics have been included. In addition, twenty-four specifications, methods of test, recommended practices, and definitions applying to plastics in the electrical insulating field are covered, this portion of the work being under the jurisdiction of Committee D-9 on Electrical Insulating Materials.

Published recently by the Gray Iron Founders' Society, a pamphlet entitled "Cast Iron in the Chemical and Process Industries" gives extensive data on the corrosion rates of cast iron exposed to the action of commonly used chemicals. Results of laboratory tests with more than 300 such corrosive media are listed along with tables showing present cast iron applications. Factors dictating various cast irons for corrosive or chemical service, the availability of the material, design for chemical industry equipment, and many specific applications are discussed in this interesting up-to-the-minute publication. Comprising 28 pages, it is available at $1.00 from the Gray Iron Founders' Society, Cleveland, or Washington, D. C.

PROFESSIONAL VIEWPOINTS

MACHINE DESIGN welcomes comments from readers on subjects of interest to designers. Payment will be made for letters and comments published

" . . . important detail missing"

To the Editor:

Metal spinning is an art and there is very little information to be found in textbooks and technical literature. I welcome all the more your article "Production Processes . . . Their Influence On Design, Part II—Metal Spinning" in the August issue of MACHINE DESIGN. However, one important detail was missing and that is the speeds for spinning the various metals. I have been figuring on 2400 feet per minute for cold rolled sheet steel 1/16-inch thick. If you have values available for steel and other metals I would appreciate hearing from you.

—H. J. ZIMMERMANN, *Chief Engineer*
Mercury Clutch Corp.

Mr. Zimmermann's point as to spinning speeds is indeed well taken. General data on speeds most certainly should have been included in the discussion.

As is recognized readily, no hard and fast rules can apply to spinning speeds. This is normally governed by size or diameter, thickness, and temper or workability of the piece of metal to be spun. The larger or heavier the blank, the slower the speed. Owing to the fact that spinning speed in surface feet per minute varies widely over a medium or larger size blank it is difficult to maintain an optimum speed on all portions. Consequently speeds usually are given in rpm and are as follows:

Zinc	1000 to 1400 rpm
Silver	800 to 1000 rpm
Brass and Aluminum	800 to 3000 rpm
Soft Steels	300 to 600 rpm
Nickel and Nickel Alloys	250 to 1000 rpm
Magnesium	300 to 450 rpm
Copper and Copper Alloys	1200 to 2400 rpm
Stainless Steels	150 to 300 rpm

These speeds apply to parts up to approximately 20 inches in diameter. Small parts of course take the higher side of the speed range. Larger parts, especially those near the maximum size or thickness handled, must be worked at relatively slower rates. For instance, a 1/32-inch thick steel disk normally spun at 600 rpm would, if increased to 1/16-inch in thickness, be spun at about 450 rpm, etc. Relatively large aluminum parts—30 inches in diameter or over—require a peripheral speed under 3000 feet per minute, this speed diminishing considerably as the size increases. Excessive speed will cause a disintegration of the metal in the early stages of breakdown operations.—ED.

" . . . materials data helpful"

To the Editor:

Your staff has done an excellent job of compiling into a convenient form in your MATERIALS WORK SHEETS a vast amount of data which, to most of us, would be rather difficult to obtain otherwise.

—H. A. BOLZ, *Assoc. Prof. of Mech. Eng.*
Purdue University

" . . . standards progress pleasing"

To the Editor:

The article "International Standards Conference Makes Good Progress" which appeared in the November issue of MACHINE DESIGN was indeed welcome. It was pleasing to see the amount of progress that has been made in this endeavor to reach an international understanding and agreement on design standards.

I think it should be recognized at the outset that, on highly stressed and heat treated steels, the Whitworth form of thread is definitely to be preferred to the American standard. There is an appreciable difference in the stress concentration at the root of the radius fillet in the Whitworth thread as compared with our truncated design. The advantage is enough to justify serious consideration of this design. Unfortunately, however, the adoption of such a standard would lose for us interchangeability between parts manufactured to the old standard and those manufactured to the new. The economic cost of such a change would certainly be enormous and I am inclined to believe, would undoubtedly destroy any possibility for the adoption of such an improved standard. However, it would seem that a 60-degree V-form thread with fillets at crest and root could be arrived at which would retain interchangeability with the present form. The fillet of the male thread could be made comparable to that of the Whitworth, but the fillet of the female thread would have to be smaller.

How to reconcile such a standard with our British

friends I confess I fail to see. They would lose interchangeability, and while undoubtedly the investment and consequent loss in their country would be much smaller than ours, the loss to each of the many companies involved would be just as great proportionately.

With whatever form thread that is proposed, careful consideration should be given to the matter of a lower stress concentration. On the latter score I believe that very careful photoelastic studies would pay.

The difficulty of a compromise on drafting standards seems even greater. Our own practices differ from plant to plant, and to such an extent that when manufacture of parts for someone else is undertaken in any quantity, it is quite common to redraw the customer's drawing to conform to one's own practice. I think it will be found that during the war, the British Rolls-Royce engine drawings were not the only ones redrawn, but also many others made in our own country. I am inclined to feel that this will always be the case and practices will necessarily vary according to individual peculiarities existing at each plant. It is well to strive toward greater uniformity but it should also be recognized that this very individuality is in itself the quality which makes for progress. It should not be completely sacrificed.

—R. E. Orton, *Chief Engineer*
Acme Steel Co.

" . . . favors standardization"

To the Editor:

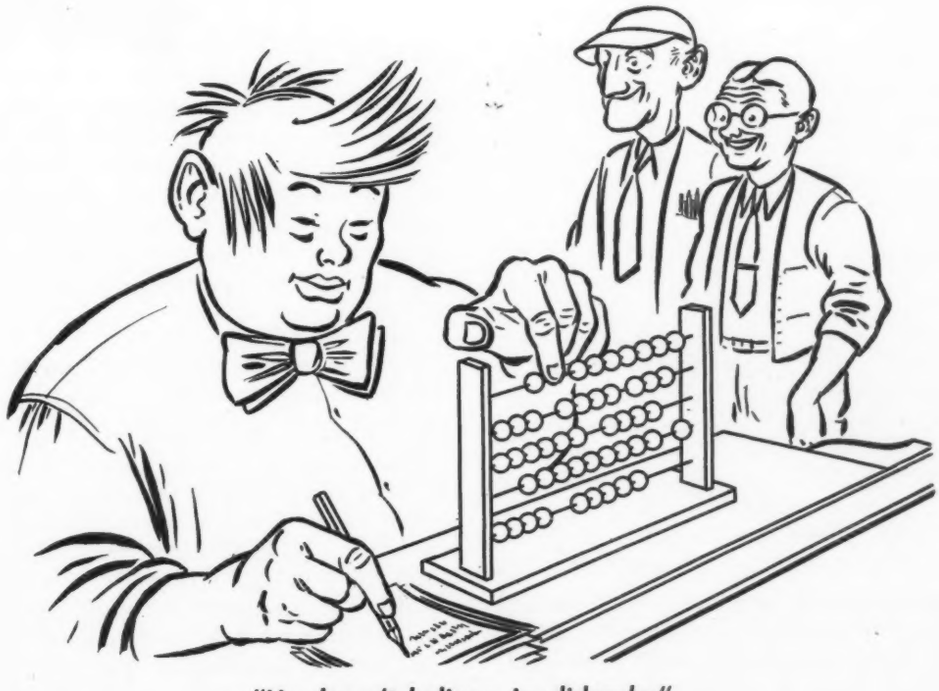
Most standards engineers endeavor to keep informed as to the progress of all efforts toward the formulation of helpful national and international standards. Your article "International Standards Conference Makes Good Progress" in the November issue was of interest in this respect.

It is pathetic, but true, that it takes a world-wide conflict to jar us from our complacency regarding ordinary standards such as those for threads, fits and drafting practice. Having experienced first hand, many of the difficulties due to limited standardization during ordnance field service in France in World War I, the writer has naturally favored every attempt to improve such conditions.

Any firm, which accepts world-wide trade, finds many design problems in adapting its products to the numerous standards common to the nations who order their goods. It is only necessary to mention for instance the subject of electric motors to illustrate the multiplicity of frequencies required to supply equipment for the world market. The present effort in standardizing electric motors is very commendable and should be extended internationally.

International standards for screw threads, pipe threads, drawing practice, and fits are more than welcomed by alert standards departments, as well as manufacturers in general. The obvious advantages, even though they cause some intermediate confusion and changes, will eventually warrant their adoption and become equally as beneficial in peace time as in war periods. If for no other reasons than efficient maintenance of equipment and the elimination of some of the waste of our fast dwindling natural resources, these international standards conferences deserve strong support. They tend to break down many little misunderstandings which add to the cause of world conflicts. Michaelangelo is quoted as saying, "Trifles make perfection but perfection is no trifle", and this might be well applied to international standards.

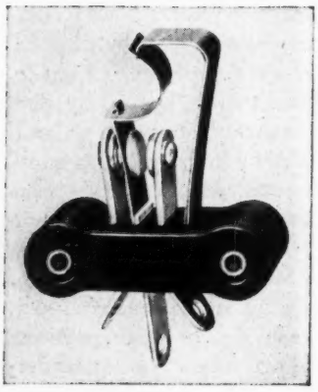
—M. W. Elmendorf, *Standards Div.*
Taylor Instrument Companies



"He doesn't believe in sliderules"

NEW PARTS AND MATERIALS

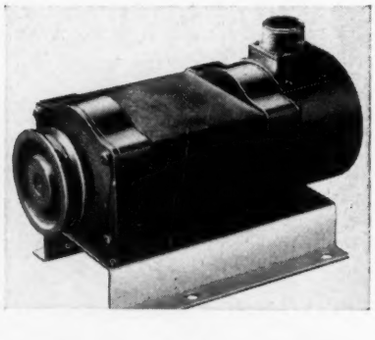
Open-Blade Snap-Switch



IDENTIFIED AS Model M, a new type smaller size open-blade snap-switch offered by Acro Electric Co., 1311 Superior Ave., Cleveland 14, fills the need for a compact switch for vertical mounting. For mounting in multiples as well as singly, the switch has an operating blade, center blade and patented rolling spring of a heat-treated beryllium copper to withstand high capacity and give long life. Standard operating pressure is 6 to 10 ounces. Furnished for single-pole, normally open, normally closed, and double-throw circuits, the switch is approximately 1 13/32 x 1 1/64 x 5/16 inches in size. It is rated at 15 amperes, 125 volts alternating current, and 1/3 horsepower, 110 volts alternating current.

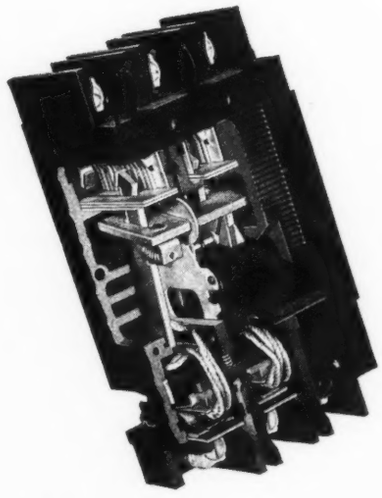
Lightweight Generator

CAPABLE OF supplying up to 1200 watts in continuous duty and weighing one-half as much as formerly available equipment, a new lightweight generator has been developed by Electrical Engineering & Mfg. Corp., 4606 West Jefferson boulevard, Los Angeles 16. Weighing 20 to 25 pounds, depending upon rating, the generato. is available in 500, 600 and 1200-watt capacities, at 32 and 120 volts, 50-degree temperature rise. Totally enclosed, glass-insulated, it can be supplied as a two-bearing unit, or with a single bearing for direct-drive applications. An integral panel with meters and voltage regulator is also available.



Frame Circuit Breaker

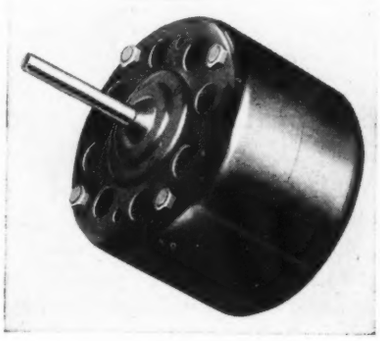
THE SWITCH and Panel Division of Square D Co., 6060 Rivard St., Detroit, has recently introduced its new ML2 100-ampere frame circuit breaker. Ratings are 15 to 100 amperes, 600 volts ac; 50 to 100 amperes, 250 volts ac-dc, two and three pole. Dust-resisting sheet steel enclosures with front-operated handle are available for 3 and 4-wire solid neutral applications in addition to 2 and 3-pole devices. Weatherproof, dust-tight and explosion-resisting enclosures are also furnished for Class I Group D and Class II Group G hazardous location applications. The breaker can also be obtained for panelboards.



Fractional HP Motors

ESPECIALLY SUITABLE for circulating and ventilating fans and blowers, centrifugal pumps, driers, timing devices, motion picture projectors, remote control drives, etc., two new four-pole shaded-pole fractional horsepower motors are being offered by Small Motors Inc., 1308 Elston Ave., Chicago. These SP-37 and SP-38 motors for duties requiring moderate torques are regularly wound for 115 volts, 60 cycle, single phase. Special voltages are available to requirements. They can be wound to stand locked rotor conditions continually, and are furnished

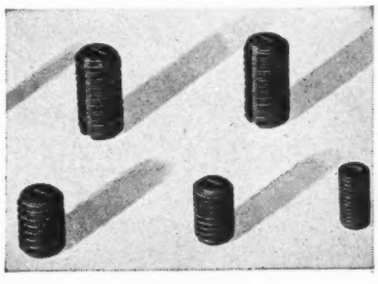
with or without fan blades, mounting brackets or bases. Operating in any position the motors are each made in four sizes: The SP-37 with ratings from 1/100 to 1/40



hp and speeds from 1400 to 1650 rpm, the SP-38 with ratings from 1/35 to 1/10 hp and speeds from 1400 to 1650 rpm.

Screw-Type Iron Cores

SCREW-TYPE molded iron cores are now being made generally available by the Stackpole Carbon Co., St. Marys, Pa. The cores are threaded and thus no brass core screw is necessary for their adjustment. Smaller assemblies are possible because the overall length of a



coil and screw-type core is small. There is no metal in the field of the coil and the cores themselves are not grounded.

Silicone Greases

TO SUPPLY THE need for high and low-temperature lubrication, Dow Corning Corp., Midland, Mich., has developed four silicone greases. Designed for lubricating ball bearings operating at abnormally high and low temperatures, these greases are characterized by high heat stability, low volatility, relatively slight changes in consistency over a wide temperature range, and low freezing points. Two of these greases, DC 31 and DC 41, are compounded almost entirely of inorganic materials. They are black in color and contain no graphite. Although possessing exceptional thermal stability, they do show a slight tendency to bleed during storage. The bleeding does not impair the performance of the greases. Corona-resistant and semiconducting because of their carbon-black content, the two greases have an electrical conductivity of 1000 ohm centimeters. The other two greases, DC 33 and DC 44, are light brown in color and are compounded with metallic soaps selected for their heat stability. They are serviceable at temperatures as high as the melting points of the metallic soaps, and show very little tendency to bleed. Of the four greases, DC 31 and DC 33 are designed primarily for low-temperature lubrication but also operate efficiently at elevated temperatures. DC 41 and DC 44 are designed for high-temperature lubrication.

Coatings for Cadmium and Zinc

AN OUTSTANDING advantage of the new process, Unichrome Dip, announced by United Chromium Inc., 51 East Forty-second St., New York 17, is that parts require only a single immersion, for from 2 to 5 minutes, to obtain corrosion protection coatings on cadmium and zinc. By converting the surface to chemically inert compounds, either black or olive drab finishes can be produced which prevent formation of white corrosion products and also provide a good base for paint or lacquer. No special equipment, racking or current is required; parts are handled in bulk and treated at room temperature.

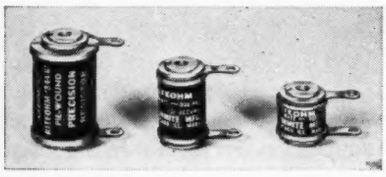
Dual-Purpose Mountings

DUAL-PURPOSE mountings for eliminating vibration and providing a means of leveling machinery of any size, type or weight, have been announced by Bushings Inc., Coolidge Highway at 14 Mile Rd., Royal Oak, Mich. Known as Vibro-Levelers they are manufactured in nine sizes, ranging in load capacities from 10 to 2000 pounds each. For use on such noise and vibration producing equipment as punch presses, compressors, blowers, forging hammers, grinders, buffers, etc., the mountings can be installed quickly with no floor cutting or fitting. Being of synthetic rubber, the insulating material employed is not liable to attack by oils or greases. It separates an outer shell, which forms the base of the mounting, from an inner cylindrical member to which is fastened a single stud. Leveling is by means of two nuts supplied with each mounting; one for adjusting the machine to the exact level desired, the other for locking in the leveled position. Standard brackets are of two types: Zee and angle. The zee-brackets are for attaching to the existing hold-down bolt holes in the base of the machine, and

require no cutting or welding. The angle type is for mounting to the side of the machine base with either bolts or by arc welding.

New Series Precision Resistors

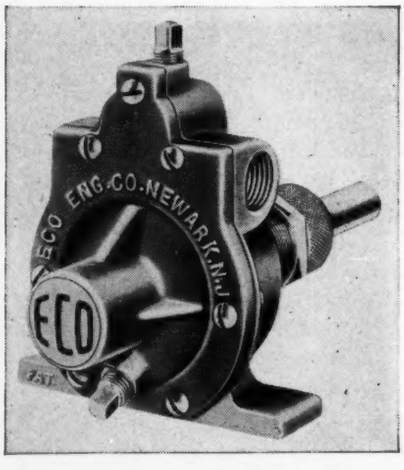
LATEST ADDITION to the Riteohm precision resistor line of Ohmite Mfg. Co., 4835 Flournoy St., Chicago 44, is the new Series 84 in Types 844B, 844A and 842A. Developed to meet the demand for a precision resistor capable of being mounted by means of a through-bolt and equipped with a radial lug at each end, the new resistor is pie-



wound to one per cent accuracy and is available in three sizes—9/16-in. diameter by 9/16-in. long, 9/16-in. diameter by 7/8-in. long, and 3/4-in. diameter by 1 3/16 in. long. The smallest is a two-pie while the other two are four-pie units. Minimum resistance is 1.0 ohm for the two-pie unit and small four-pie unit, and 0.10 ohm for the large four-pie unit. Maximum resistance is 200,000 ohms for the two-pie, 400,000 ohms for the small four-pie, and 1.5 megohms for the large four-pie unit.

Improved Gearless Pump

INTRODUCED BY Eco Engineering Co., Dept. 69, 12 New York Ave., Newark 1, N. J., the improved gearless pump for water, light oil or other liquid circulating use, is



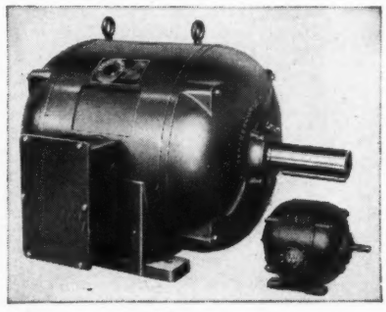
equipped with special bearings which require only water lubrication. For use in oil or fresh or salt water, the pump can be mounted at any angle and operated in either direction. Opening of the face plate allows quick removal of any obstructing material. The removable impeller is of tough resilient material composed of several layers of laminated sections, vulcanized together under pressure. It enables sandy, muddy, or gritty particles to pass without harm to the pump. Available with single impeller and standard ½-inch connection or double impeller with standard 1-inch connection, the pump is constructed for long service.

Lubricant for Bearing Motors

AN IMPROVED GREASE for ball and roller bearing motors is now available from Westinghouse Electric Corp., East Pittsburgh, for lubrication requirements from 13 to 176 F, for all speeds up to 3600 rpm and for horizontal or vertical operation. The grease, furnished in an 8-ounce nasal-type tube is highly resistant to oxidation and will remain in a bearing for an indefinite period without drying out, caking or separating. The long nasal spout fits into a one-eighth inch pipe coupling.

Protected-Type Motors to 200 HP

WITH THE ADDITION of three new frame sizes, designated as B58-A and C, Crocker-Wheeler Division of Joshua Hendy Iron Works, Ampere, N. J., now offers a



complete line of alternating-current, squirrel-cage protected-type motors from 1 to 200 horsepower. Providing protection against dripping liquids, falling metal chips and other foreign matter, the motors are built in NEMA standardized frames (203 to 326 inclusive) and have no openings in the frame or shields above the horizontal center line. NEMA standardized frames 326 to 505, as well as the three, newly added, larger sizes are basically the same in construction with the addition of two shielded, air exhaust openings in the upper half of the frame. Incorporation of the company's centrifugal bearing seal permits the use of softer grease for better lubrication and longer bearing life.

Ceramic with Dimensional Stability

POTENTIAL USES for a new ceramic, known as Material M-244 and offered by General Ceramics & Steatite Corp., Keasbey, N. J., include applications in high-temperature furnaces, as insulation for high-precision instruments in which dimensional changes must be minimized, and for many electrical and electronic purposes demanding a low

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● Regardless of the type of product that you manufacture . . . or the method used in manufacturing . . . you can secure excellent, competent bearing advice . . . plus top quality bearings at Johnson Bronze. We can help you select the *correct* bearing for your product . . . the one that will deliver the greatest amount of service for the longest period of time. For maintenance and repair we offer you the largest range of sizes in stock bearings available. Remember . . . we are the only bearing manufacturer that produces ALL TYPES of Sleeve Bearings. May we work *with* you now?

JOHNSON BRONZE COMPANY

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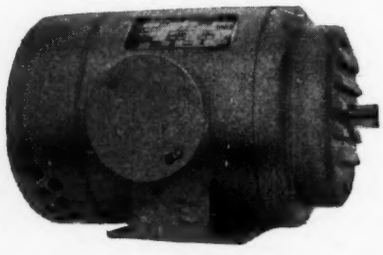
thermal expansion coefficient in ceramic parts. In a test, the ceramic was heated to a temperature of 1400 F and then plunged into an ice water bath without cracking and without dimensional change at either temperature extremes. According to the company, plans are to supply this material in any shape that can be formed by pressing, extruding or casting. The ceramic can withstand a temperature of 2500 F.

Small Direct-Current Motors

RATED AT ONE-HALF horsepower with an input of 18 amperes, Model 1/2 DVO7 direct-current motor developed by Kato Engineering Co., Mankato, Minn., is approximately 10 5/16 x 7 3/32 x 7 inches in size. Weight is 45 pounds. The motors have ball bearings with grease seals and are sufficiently lubricated for life. Lubrication can be replenished by removing metal disks which are held on to both ends of motor with three small machine screws. To permit mounting motor in any horizontal position (motor is dripproof in this position), both the louvered



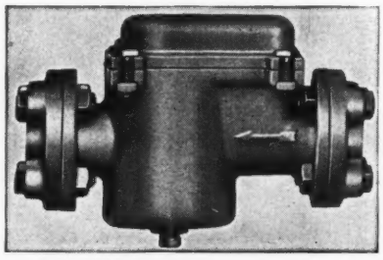
cover and commutator end cover can be rotated. Motor can also be vertically mounted if desired. These motors are available for 110 and 220 volts direct current. In the accompanying illustration a 1/2-horsepower motor is shown. Other available sizes include the 1/3 and 1/4 horsepower types, while still others may be obtained upon specification. Of rugged construction, the motors are designed with a generous use of steel and copper. Endbells are steel and frame is molded and welded. The cover is drawn steel. The motors are equipped with a device for suppression of radio interference.

Signal Relay Connector

ADAPTABLE TO all makes and types of relays used in railway signal relays, Type RR-1 and RR-2 connector manufactured by Cannon Electric Development Co., 3209 Humboldt St., Los Angeles 31, is a new departure in fittings of this type. While it is specifically designed for the signal field, it is also suitable for use on transformers, rectifiers, etc. Complete connector is made up of a plug and receptacle, having phenolic shells. Receptacle is mounted on the board or back wall of the relay instrument, and contains pin contacts. Plug portion is removable, and can be engaged or disengaged in 13 seconds. Through the use of two guide posts correct polarization is assured. There are no soldered connections but rather standard wire terminals are used over the studs, with a ⅝-in. hexagon nut, having 14-24 thread. This new connector is adaptable to four or six-point relays where space allows.

Low-Swing Strainer

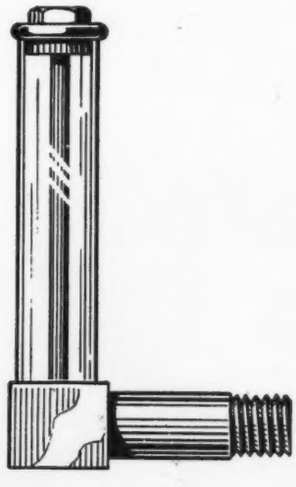
SOME OF THE advantages of the new low-swing strainer brought out by The Blackmer Pump Co., Grand Rapids, Mich., include the following: The strainer basket is perforated steel or bronze; slotted lugs of the top plate line up with lugs of the strainer body to receive the four holding bolts; and compact design permits mounting in small space or in lines along walls. The strainers are designed for flange mounting. While present production is limited to a capacity of 100 gallons per minute with 2-inch,



2½-inch and 3-inch intake and discharge sizes, the strainers will eventually be available in larger and smaller sizes. Maximum operating temperature of the pumps is 600 F. Maximum pressure is 75 psi.

Oil Gages with Good Visibility

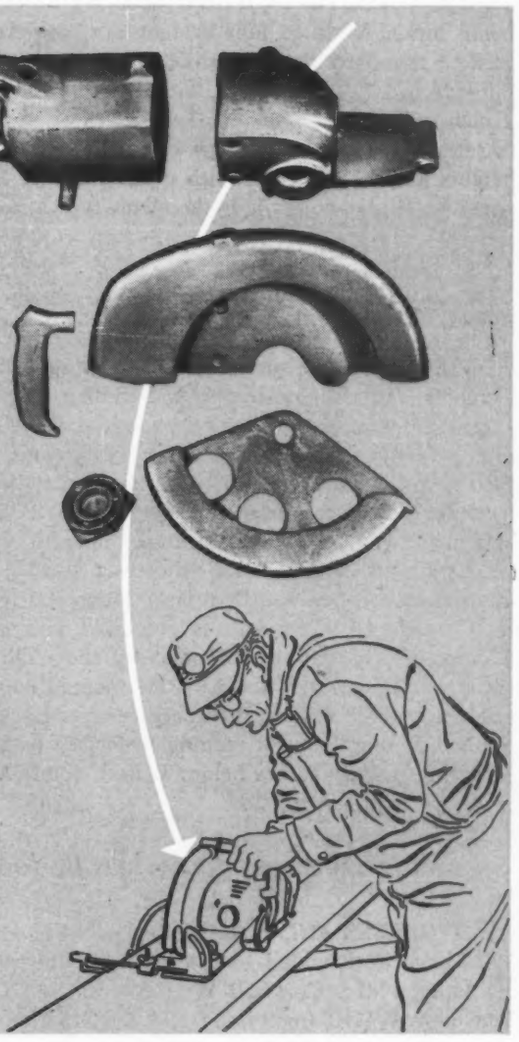
AVAILABLE IN a complete range of sizes and styles, the new oil gages announced by Oil-Rite Corp., 3476 South Thirteenth St., Milwaukee 7, combine excellent visibility and unbreakable sights in a simple construction. The gage body is brass while the sight is of unbreakable



plastic, eliminating the protective shell and thus offering more visibility. The sight is supported by a heavy central stem and a top cap. Leakage is obviated by the assembly

Where lightness cuts . . . fatigue

cuts time . . . cuts labor . . . cuts cost



Here's a sturdy portable power saw built to cut more than lumber! It's cutting *expenses* on many a job. Skillful design, with *lightweight magnesium*, has held its weight down to 36 pounds.

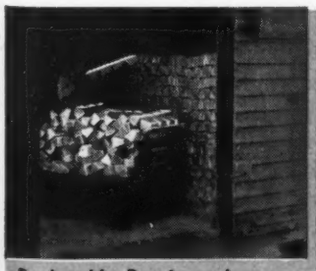
This product is regarded by its manufacturer, The Mall Tool Company, as the most powerful saw of its type for making heavy cuts. Its combination of lightness and strength owes a great deal to the durable magnesium castings that form the motor housing and back handle, weighing only 2½ lbs.; gear housing, 3½ lbs.; upper guard, 2 lbs.; lower guard, 1 lb.; front handle, ¼ lb.; and bearing cap, ⅓ lb.

It's one of many fine new products making use of magnesium. For further information, contact the nearest Dow office.

Ready . . . to make products move!

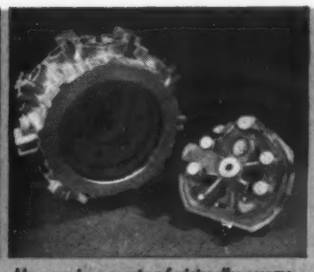
MAGNESIUM

LIGHTEST OF ALL STRUCTURAL METALS

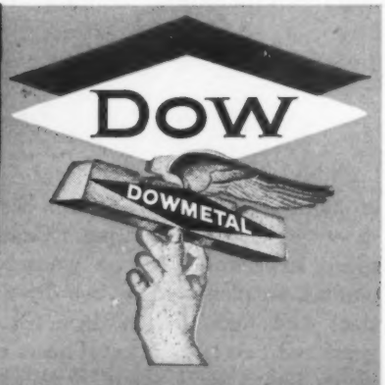


Produced by Dow in ample quantities, magnesium metal is now freely available in all common forms for widespread use.

Many modern plants throughout the country are working with magnesium, following standard procedures and shop techniques.



Magnesium parts of virtually every size and description are being used in a growing variety of fine new products of many kinds.



MAGNESIUM DIVISION • THE DOW CHEMICAL COMPANY, MIDLAND, MICHIGAN

New York • Boston • Philadelphia • Washington • Cleveland • Detroit • Chicago • St. Louis • Houston • San Francisco • Los Angeles • Seattle

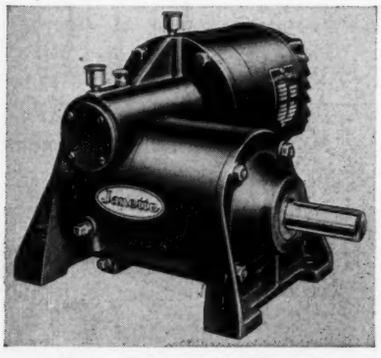
being locked with an independent nut, compressing the gasket. Standard sizes in which the gages are available range from 1 1/4 to 5 inches, with sight diameter of 1/2 to 1 inch with stock threads of 1/8, 1/4, 3/8 and 1/2-inch National Pipe Threads. Gages can be furnished in special heights and lengths, also with drain plugs or in straight gages for applications where the elbow type is not suitable.

Strippable Plastic Coating

PROTECTION OF manufactured parts against corrosive elements and dangers of rough handling in packing or shipping operations is attained by use of Eronel Thermo-dip, recently introduced by Eronel Industries, 5714 W. Pico Blvd., Los Angeles 35. Skin-tight coatings and easy final removal of the protective film (which is reclaimable and may be re-used) are advantages offered by this new plastic strippable compound. Resisting humidity, impact, abrasion and corrosion, the process is applied by the "hot melt" method. When part is immersed into the melted Thermo-dip, a coating is formed by the chilling of the compound adjacent to the part. Subsequent cooling hardens the coating to a film. It remains transparent, and can be applied at temperatures ranging from 280 to 325 F, approximately 100 degrees below its flash point.

Motorized and Motorless Reducers

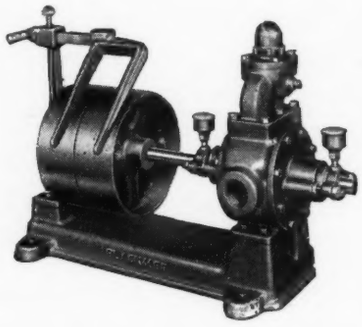
MOTORLESS AND motorized speed reducers in a new style have been added to the line of reducers produced by Janette Mfg. Co., 556 West Monroe St., Chicago 8. The new W1DP (motorless) and the R1DP (motorized) units are the same as Style W1P and R1P reducers which have been on the market for many years, with the exception that the new style are double planetary units. Combination of worm and planetary gearing permits use



of high-speed motors of from ⅛ to ¼ hp, with output speeds as slow as 1.89 rpm. Gearing consists of a high-speed steel worm, bronze worm wheel, two high-speed pinions, six planet gears, two drive plates each with three steel studs mounted in them for supporting the planet gears and two large interval gears cut on the inside of the heavy, nickel iron housing of the gear box. The planetary gear units can be assembled on either side of the speed reducer which can be furnished with either foot or flange base mounting. Weight of the motorless speed reducer is approximately 63 pounds; the motorized, the same plus the weight of the driving motor.

Motor-Driven Rotary Pumps

FLAT-BELT AND direct motor drive rotary pumps in capacities from 10 to 750 gallons per minute at pressures up to 100 psi have been adapted to filter and transfer applications in dry cleaning equipment. The 10, 20, 35 and 50 gallons per minute units are now available for prompt delivery from the Blackmer Pump Co., Grand Rapids, Mich. Pumps are designed to operate on the "bucket design" (swinging vane) principle and because of this are self-adjusting for wear. Buckets move out of the recesses of the rotor as wear occurs at tips. This compensating action maintains normal capacity of pump until buckets are worn



to replaceable point. Buckets are replaced by removing head plate of pump. This same type pump is also furnished with removable liners so that when abrasive action of dirty solvent wears both liner and buckets they may be replaced.

Capacitors with Removable Brackets

SMALL RECTANGULAR-CASE capacitors can now be obtained from General Electric's Transformer Division, Pittsfield, Mass. Having removable mounting brackets, the capacitors are designed for either a-c or d-c applications. The brackets can be clamped over either the top or bottom-flange of the case, permitting mounting in an upright or inverted position. They have a U-shaped foot with a reverse bend which projects under the mounting surface of the capacitor. Mounting foot is sufficiently flexible to compensate for normal tolerances in the case heights, and allows brackets to be clamped to the unit when mounted. This construction minimizes stress on the mounting surface, preventing distortion of a metal chassis when unit is clamped into place. The brackets, die-formed from steel punchings, have a durable, corrosion-resistant finish of lacquered zinc plate.

Dual-Valve Pumps

PRODUCED IN TWO models, a new Titan pump of Candler-Hill Corp., 405 Midland Ave., Detroit 3, is available with capacities of 830 and 1600 gph at 2500 rpm.

"CLUTCH HEAD SCREWS STEPPED UP PRODUCTION 20%" Say

LINDSAY & LINDSAY

Chicago manufacturers of the famous Lindsay Structure for all-metal truck body assemblies . . . serving America's largest fleet owners through a Nationwide organization of Distributors and Builders.

This Increase **is definitely accredited to CLUTCH HEAD as compared with the use of other recess head screws in the regular assembly schedule . . . the result of exclusive features that contribute to faster, safer, easier, and smoother power driving. It will pay you to investigate these factors.**

HIGH VISIBILITY . . . Wide roomy recess is an easy-to-hit target. Substitutes operator confidence for slow-down hesitation. Saves "breaking-in" period.

AUTOMATIC STRAIGHT DRIVING . . . No driver canting because the Center Pivot column guides the bit into full-depth dead-center engagement.

NO CHEWED-UP HEADS . . . to stop or slow down the line. Definite grip protects manpower and material against slippage.

EFFORTLESS DRIVING . . . With CLUTCH HEAD the driving contact of bit and recess walls is all-square. No ride-out or "kick-back" as set up by tapered driving.

ABSENCE OF END PRESSURE . . . disposes of a fatigue factor and a slippage hazard. Steps up speed for smoother higher production . . . no end-of-shift lagging.

DRIVE EXTRA THOUSANDS OF SCREWS . . . with the rugged Type "A" Bit . . . without interruption for tool change.

NEW BIT LIFE IN 60 SECONDS . . . No back-to-the-factory shipment for reconditioning. A simple 60-second application of the end surface to a grinding wheel restores this bit to its original efficiency . . . *time and time again.*

THE CLUTCH HEAD LOCK-ON . . . A reverse turn of the bit in the recess unites screw and bit as a unit for easy one-handed reaching to hard-to-get-at spots. With the Type "A" Hand Driver for field use, this Lock-On enables service men to withdraw screws undamaged and held safely for re-use.

OPERATES WITH ORDINARY SCREWDRIVER . . . This is the only modern screw basically designed for operation with a flat blade which need only be reasonably accurate *in width.* Simplifies field service problems.

The many advantages of CLUTCH HEAD *Screws and of the Type "A" Bit are self-evident upon examination. You may convince yourself by sending for package assortment of screws, sample of the Type "A" Bit, and illustrated Brochure. Mailed to you without obligation.*

CLUTCH HEAD SCREWS

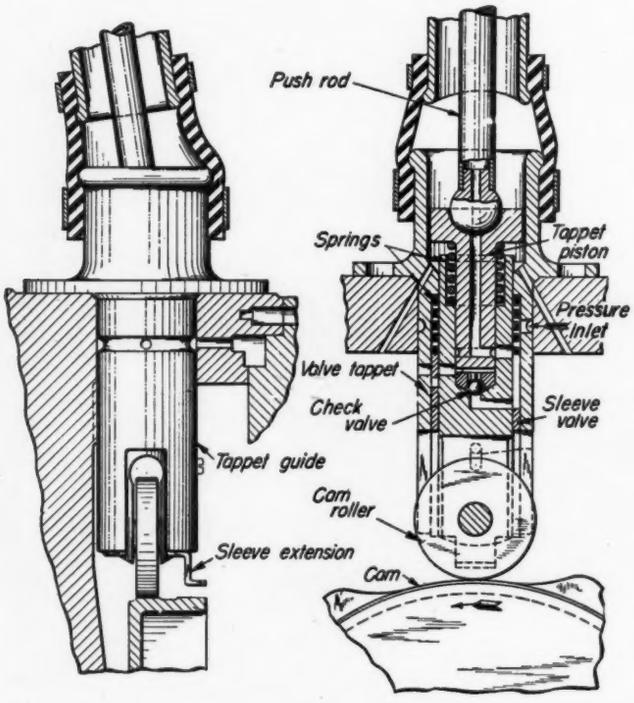
UNITED SCREW AND BOLT CORPORATION

CLEVELAND 2 CHICAGO 8 NEW YORK 7

Noteworthy Patents

Hydraulic Tappet

DESIGNED to permit a new adjustment to minimum clearance between each actuation of a valve tappet, an unusual hydraulic arrangement covered by patent 2,386,317 was recently assigned to the Wright Aeronautical Corp. Especially intended for radial aircraft engines, the tappet mechanism shown in the accompanying illustration



A sleeve valve actuated by the passing exhaust cam lobe relieves hydraulic pressure within the tappet chamber providing a constant readjustment of takeup

automatically corrects for actuating cam lobe variations and also variations in valve clearance caused by temperature changes during operation.

In a conventional radial cylinder aircraft engine, the intake and exhaust valves are mounted adjacent to each other on the crankcase. Consequently in operation, after a cam lobe has actuated an intake valve tappet for a particular cylinder, an exhaust valve operating cam lobe will pass this intake valve tappet prior to the next actuation of the valve. This invention utilizes the passage of the exhaust cam lobe to reciprocate a sleeve of the intake tappet mechanism and relieve hydraulic pressure before the next tappet movement. Similarly, the movement of the intake valve cam lobe is used to relieve hydraulic pressure within the exhaust tappets after each actuation.

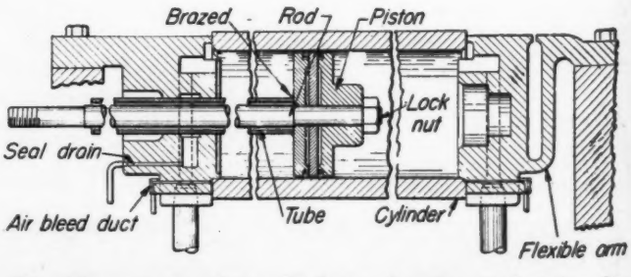
In the illustration, the valve and tappet are in closed position and oil pressure entering the inlet port and passing through the check valve acts upon the tappet piston to take up clearance. When a cam lobe operates the tappet through the roller, the check valve prevents escape of oil from the tappet piston chamber. After return of the tappet and valve to closed position, an exhaust cam lobe engages the sleeve extension, raises the sleeve valve, and opens the tappet piston chamber to drain. Simultaneously with this relief of pressure in the piston chamber, the sleeve valve also cuts off pressure from the inlet port. On release of the extension, a spring returns the sleeve valve to initial position. Thus oil pressure entering through the check valve will again take up the then existing clearance in the valve operating mechanism prior to the next actuation of the tappet.

Eliminates Machine Distortions

EXPRESSLY designed to obviate distortions usually present in normal hydraulic cylinder arrangements is patent 2,371,553, recently assigned to the Heald Machine Co. Shown in the accompanying illustration, the cylinder is for reciprocating table actuation and so arranged as to reduce the effect of expansion in the unit as the hydraulic fluid heats it up in operation. Utilizing a packless floating piston rod, the cylinder also eliminates all friction produced by ordinary packings.

A flexible arm connection for attaching the cylinder to a machine bed supports it rigidly in all planes but allows free expansion in the horizontal plane without transferring it to the bed. To obviate problems of rod packings and rod misalignments, a hollow tube brazed to the piston acts as the sealing member, being an extremely close fit in the cylinder head. A recess at the sealing point drains away the small amount of oil that is carried over. Flexing or movement of the rod proper is thus permissible without adverse effects.

Unusual compared to most designs is the piston. Made of three pieces, the piston allows assembly of piston rings without need for distorting them out-of-round. Accuracy of rings is thus retained. Tightening of the rod lock nut enables an exact final adjustment of the piston sections to provide proper ring width clearance.



Flexible mounting for cylinder and rod unit obviates distortions caused by expansion or misalignment

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Design Abstracts

Hydraulic Power for Farm Machinery

APPLICATION of hydraulics to farm machinery will have the extremely important effect of equating to a large extent the physical capacity of the farmer with the productive capacity of his tractor-implement combination. Since the biggest barrier to full utilization of farm machinery has been the limitation of human strength, the contribution of hydraulics in saving manhours, conserving muscular energy and adding to machine efficiency will be a major one. Because of the strict cost limitations connected with all farm machinery, prompt progress in the standardization of hydraulic equipment is especially important.

Among the numerous advantages of hydraulic control are:

1. Absence of exposed belts, chains, gearing, shafts, bearings, clutches, and other troublesome and dangerous parts, so that safety shields are unnecessary
2. Elimination of space interferences and many lubrication problems
3. Solution of the problem of getting power around corners
4. Possibility of delivering a given torque at varying speeds by varying the amount of oil transmitted to the fluid motor, either through the displacement rate of the pump or by valving in the intermediate system
5. Provision for automatic overload protection in the case of abnormal obstruction to movement.

Hydraulic application has failed to find universal acceptance in the farm machinery field chiefly because of the expense occasioned by lack of standardization in mounting and drive equipment, and also because engineering application work has not yet been extensive enough to apply hydraulic power to all the farm tasks for which it is fitted.—*From a paper by L. R. Twyman, Vickers Inc., presented at a Milwaukee section meeting of the SAE.*

Combining Plaster and Plastics

IMPREGNATION of plaster of paris with liquid thermosetting resins and the subsequent conversion of the product with heat results in the formation of an entirely new material which has been called "Plaspreg". The resinified plaster body still retains the crystalline structural network formed on the hydration of $2CaSO_4,H_2O$, though considerably augmented through infusion with synthetic resins. In appearance and feel the impregnated plaster body resembles a cast plastic material more than it does the ordinary plaster-of-paris bodies, though the improvements which are possible extend much further than the appearance, as all properties are greatly enhanced.

Among the applications are master models built of plaster of paris (weighing several hundred pounds) which have been rendered much harder and more permanent through proper impregnation of furane resin; dies for hydropress operation in forming sheet metal; Keller pattern and duplicating dies; core boxes for the foundry; forms for laminating polyester resins; contoured shapes for shaping acrylic plastic; and patterns of industrial and decorative value.

Shrinkage Is Negligible

This development represents the advent of a new thermosetting resin—the 100 per cent furane resin—into the plastics picture and the development of a new and important outlet for plastics in the ceramics industry. A new, low-cost tooling material with negligible shrinkage has made its appearance.

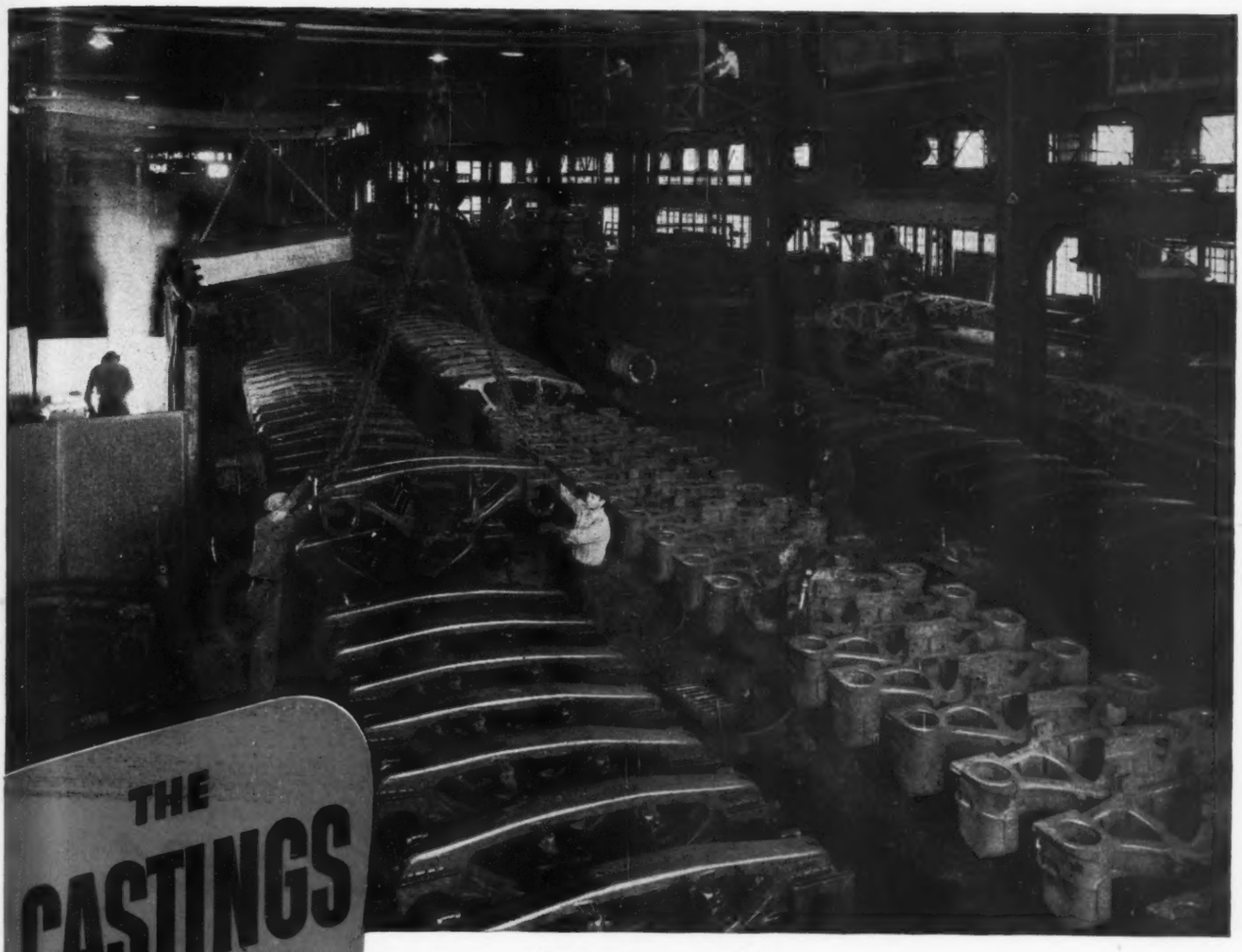
Advantages include:

1. Low cost: "Plaspreg" is prepared from base material which costs about 1 cent per pound. Even when fully impregnated, the cost of "Plaspreg" is less than that of a thermosetting cast phenolic resin
2. Ease of fabrication: From this standpoint, plaster has few equals. In the "Plaspreg" process, plaster or hydrocal tools, forms, or patterns are prepared in the usual manner and set at room temperature. A stable structure is prepared with simple tools. Upon resinifying and hardening, this form is rendered permanent
3. Physical, chemical and thermal properties: These properties have been vastly improved over the straight plaster—placing the fully impregnated material in the same class as liquid cast resins—with the important advantage of zero after-shrinkage
4. Application: No form is too small or section too big to be handled. Resin penetrations up to several inches have been accomplished at room temperature and atmospheric pressure. Wherever plaster is used, resin impregnation may be applied to convert these articles to permanent, stronger materials of construction.

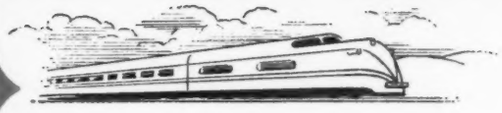
Disadvantages include:

1. Drying: For best results the plaster forms should be thoroughly dried out. This necessitates an additional step in preparing plaster and lengthens the time lapse before the part can be used
2. Breaking: While all properties are improved some 300-400 per cent, "Plaspreg" forms can still be broken, and one should not expect the treatment to convert plaster into a rubber-like unbreakable material.

—*From a paper by John Delmonte, consulting engineer, Furane Plastics & Chemicals Co., presented at the ASME annual meeting in New York.*



THE CASTINGS THAT KEEP ROLLING STOCK *Rolling*



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W&D 9865

D. J. Sweeney

Dr. Charles H. Herty Jr.

James M. Hait

MEN...of...machines

D. J. SWEENEY, well-known in the radio industry, is now heading up the mechanical design group of the advance development and research section of The Crosley Corp. Mr. Sweeney began his radio career with the Westinghouse Electric & Mfg. Co. With the formation of the R. C. A. Victor Mfg. Co., he joined the special apparatus division, located in Camden, N. J. In this capacity he was responsible for the mechanical design of much of the early short-wave apparatus produced by R. C. A. He joined the General Electric Co., Bridgeport, Conn., in 1934 as home receiver radio design engineer, and held this position up to the time he left to join Crosley as chief mechanical development engineer. In his new post he will be responsible for advance development and research work in radio, television, and refrigeration as well as in the home appliance field.

DR. CHARLES H. HERTY JR. was recently elected president of the American Society for Metals. He is assistant to vice president at Bethlehem Steel Co., a position he has held since 1942. Dr. Herty was born in Athens, Ga., in 1896, and after preparatory schooling at Asheville, attended the University of North Carolina where he graduated in 1918 with a Bachelor of Science degree in chemical engineering. During 1918 and 1919 he was engaged in the Chemical Warfare Service of the United States, and in 1924 received the degree, Doctor of Science, from Massachusetts Institute of Technology. After serving with the U. S. Bureau of Mines, Pittsburgh, from 1926 to 1931, Dr. Herty was appointed director of research, Metallurgical Advisory Board, Pittsburgh. In 1934 he joined the Bethlehem Steel Co. as research engineer and in 1942 was made assistant to vice president. An author of numerous articles on melting and refining of steel, Dr. Herty is a recipient of the Albert Sauveur Achievement Award in 1943.

JAMES M. HAIT has been appointed director of engineering of the Food Machinery Corp., San Jose, Calif., succeeding A. R. Thompson retired. Mr. Hait has been manager and chief engineer of the procurement and engineering division of the corporation for the last three years. Well known as the designer of the "Water Buffalo" amphibious tank, he was born in Brooklyn, N. Y., in 1906. Immediately upon graduation from the Rensselaer Polytechnic institute in 1928, with a Bachelor of Science degree in mechanical engineering, he became affili-

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Kodak

ated in an engineering capacity with Emsco Engine Co. He left Emsco in 1930 to become chief engineer of Peerless Pump Co. Three years later when Peerless became a division of Food Machinery Corp., Mr. Hait remained as chief engineer. When the war broke out and the Navy called on Food Machinery Corp. to design an amphibious tank, it was Mr. Hait's job and the success he achieved has won the praise of the engineering field. In 1942 he was made manager of the procurement and engineering division of the corporation.

♦

FRANK W. GODSEY JR. has been named manager of the new products division of Westinghouse Electric Corp. Since joining Westinghouse in 1940 Mr. Godsey has served in the division he now directs. He has been granted some 40 electrical and mechanical device patents.

♦

REINOUT P. KROON has been named manager of the engineering department of the newly formed Aviation Gas Turbine Division, South Philadelphia Works, Westinghouse Electric & Mfg. Co.

♦

CHARLES CUMA, formerly in the engineering department of Atlas Imperial Diesel Engine Co., Chicago, has become connected with Willys-Overland Motors Inc., Toledo, O., as design engineer.

♦

A. L. BERGSTROM in his new duties as vice president of engineering of Timken Roller Bearing Co., will have complete charge of all engineering activities. He had been executive engineer for the company since 1938.

♦

CHARLES H. COLVIN, engineering consultant, has been elected president of the Institute of Aeronautical Sciences for 1945.

♦

OLIVER E. MOUNT, vice president, secretary and treasurer, American Steel Foundries, Chicago; CLAUDE L. HARRELL, vice president of Sterling Steel Casting Co., East St. Louis, Ill.; and EDWIN A. WALCHER, vice president of Ohio Steel Foundry Co., Lima and Springfield, O., were honored at the recent annual meeting of the Steel Founders' Society of America, by being presented awards in recognition of their outstanding contributions to the industry.

♦

CHARLES W. MILLER JR., who has been actively associated with the aviation industry for more than twenty years, has become a member of the engineering staff of The Briggs Clarifier Co.

♦

GERHARD MAURIC has been appointed chief engineer of Electrical Engrg. & Mfg. Corp. His extensive background in electrical engineering includes development and design of special motors and electric drives to fit unusual requirements of the industry.

♦

LT. COL. JOHN S. TAWRESEY recently has been appointed vice president in charge of engineering for The Bunting Brass & Bronze Co. He will direct research and study of modern bearing design in the light of advancements made during the war. Col. Tawresey had served at Wright Field as executive assistant to the Chief of the Resources Control Section of the U. S. Army Air Corps.

♦

JOHN SEAGREN is consulting engineer with the diesel division of the American Locomotive Co., Schenectady, N. Y. He formerly had been development engineer on postwar products for Northern Pump Co.

♦

HANS RUTISHAUSER has been appointed executive vice president of Combustion Research Co., which specializes in the production of jet propulsion motors.

♦

NIKOLA TRBOJEVICH, mathematician, inventor and gear expert, has joined Jack & Heintz as research engineer. A native of Jugoslavia and a graduate of the University of Budapest, Mr. Trbojevich came to United States in 1914 to take a student engineering course with Western Electric Co., and also to attend Northwestern University. Deciding to stay in this country, he obtained a position as an engineer with Illinois Tool Works, which he held from 1915 to 1920. During this time he achieved a reputation as a gear expert and since 1920 has been an independent inventor and consulting engineer, having acquired over 60 United States and many other foreign patents. His most notable work was the development of a new type spiral bevel and hypoid gearing together with tools and machines for its manufacture. Among his other inventions in the field of worm gears are steering gears, universal joints, pumps, gages, and gear cutting and grinding machines.

♦

ROBERT L. HARTLEY has joined Taft-Peirce Mfg. Co. as special designer. Previously he had been experimental engineer, fuel injection division, Bulova Watch Co., Woodside, L. I., N. Y.

♦

JAMES L. RAY has been made chief engineer of the Joshua Hendy Iron Works, Sunnyvale, Calif. Mr. Ray, who is the former chief gas-turbine design engineer of Allis-Chalmers Mfg. Co., will head the company's gas and steam turbine engineering department in San Francisco.

♦

BRIG. GEN. LAURENCE C. CRAIGIE, veteran Wright Field officer, has been made chief of the Air Technical Service Command's engineering division in charge of research, development and testing of Army Air Forces' airplanes and equipment. General Craigie replaces BRIG. GEN. FRANKLIN O. CARROLL who is on an undisclosed overseas mission.

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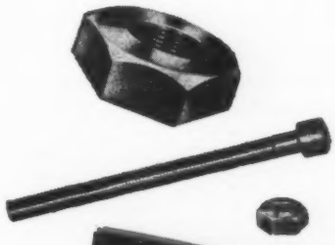

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Computing Mechanisms

(*Concluded from Page* 118)

order of the characteristic speed equation being equal to the number of time constants in the chain. The auxiliary algebraic equation of the followup will thus have the form:

$$p(T_1p+1)(T_2p+1)(T_3p+1) \ldots (T_np+1)+K=0 \ldots (25)$$

Equation 25 is then solved for the value of K that gives critical stability, as before. More than one point of critical stability may be found as the order increases, making selection of a satisfactory value of K more difficult.

Hydraulic variable-speed drives have characteristics similar to those of the electric type just discussed. One or more time delays will be present, although perhaps not in as readily recognizable form as the simple L/R time constant of a generator field. The method of analysis is precisely the same, however.

Reduction of Steady State Velocity Lag: Various means for reducing or eliminating this lag might be employed. The method suggested for the "idealized" drive (*Fig.* 51) can be used, although this involves an additional integrator or variable-speed drive. A scheme has been used with the electric type just discussed in which an additional field winding is shunted across the generator terminals in series with a relatively large inductance. The resistance of the winding is such that the slope of its current-voltage curve is practically tangent to the magnetization curve. It will thus tend to maintain any voltage at which it is operating, with a minimum of correction from the control field. Under steady state conditions, then, the control field excitation, which represents the velocity lag, will approach zero. The inductance serves to isolate the shunt field from the rest of the system, allowing it to respond only to relatively slow changes and thus not upset the stability of the followup. Whatever the method of steady-state correction, it is important that the drive not be rendered unstable. The addition of steady-state correction may sometimes require further changes in the control sensitivity in order to regain stability.

Discussion of servomechanisms will be concluded in next month's article, which will be the final part in this series on continuous computing mechanisms.

Government in Research?

(*Concluded from Page* 102)

The potentialities of the project were so vast and so uncertain in their nature that national security required full governmental control; permitting even partial monopoly by any industrial company was unthinkable; the field was so new that no participating company was jeopardizing substantial assets built up by past research and expenditure; and success might bring such benefits to the entire nation as to constitute a fully adequate reward to all who had cooperated to achieve it.

I wish to give only brief consideration to the May-Johnson bill dealing specifically with nuclear research and development. Had that bill retained its original form in which it was rushed through the House of Representatives, I would have had much to say. In its original form it was a monstrosity, setting up a commission with unprecedented arbitrary powers, superior alike to the law of contracts and Congressional control, placing American nuclear research in a strait-jacket, while leaving foreign scientists free, and providing savage penalties savoring of the Gestapo for violation of the least of its regulations. Fortunately, the Senate has been more deliberate, permitting the protests of scientists to be heard, and now the bill has been shorn of its worst features and toned down to more reasonable form. Its original is now of interest only to indicate how far astray we may be led by emotional thinking and snap judgment based on inadequate understanding.

This brings me to the final and most important item in my discussion, nuclear fission. It is by far the most important in every aspect—scientific, economic, social, military and international. When J. J. Thomson, less than half a century ago, identified the electron, who could have foreseen that electronics would bring us radio broadcasting, television, the talking movie, and the multifarious industrial applications of vacuum tubes? Electronic developments are still multiplying and increasing in utility, yet all this has come from a mere skimming of the surface of the atom, utilizing nothing more than transformations of energy. Who can doubt that now, when we have pierced to the atom's heart and have made available the creation from matter of energy in a new and tremendously concentrated form, we shall ultimately develop uses of far more fundamental importance and widespread utility than all that electronics can yield?

But such riches can be developed only by long, arduous, courageous co-operative pioneering by the world's ablest scientific minds. America must do her part, not only as an obligation due to all mankind but also in order that we may share early and in full measure in the benefits to come. Research in the basic sciences, such as is contemplated by both the Magnusson and Kilgore bills, should be limited in its extent only by the available supply of scientific brains competent to undertake such exacting research.

Seeking Ideas from Other Fields

SKILL in borrowing other's ideas is the mark of the successful engineer. Down through the fifty years of automotive engineering sound basic engineering ideas recur again and again in the evolution of the motor car as we know it today.

Many of these ideas such as high-compression engines, improved spring suspension and better riding comfort, and today's styling with multicolored bodies and trim had to wait until collateral developments in metallurgy, chemistry, and production techniques caught up to the parade of advanced thinking. The engineer who cannot peer beyond his own specialty will have only an unimportant place in the postwar world. The young engineer who dedicates himself to a thorough understanding of transportation, who can grasp the interrelationships of economics, detail design, and the overall functioning of a vehicle—whether for land, air, or sea travel—has the world before him.—*From a recent paper presented by Henry M. Crane, General Motors Corp., at a Metropolitan section meeting of the SAE.*

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		Plain	Galv.		Width	Length	Plain	Galv.		Width	Length
½″–#20	20	.50	.63	3′ & 6′ x 8′	.45″	1.2″	.47	.63	3′ & 4′ x 8′	.46″	1.28″
½″–#18	18	.74	.91	3′–4′ & 6′ x 8′	.45″	1.2″	.70	.91	3′ & 4′ x 8′	.46″	1.28″
½″–#16	18	.81	.97	4′ x 8′	.45″	1.2″	.77	.97	4′ x 8′	.46″	1.28″
¾″–#16	16	.50	.59	3′–4′ & 6′ x 8′	.95″	2.0″	.47	.59	3′ & 4′ x 8′	.97″	2.13″
¾″–#13	13	.80	.92	3′–4′ & 6′ x 8′	.95″	2.0″	.76	.92	3′ & 4′ x 8′	.97″	2.13″
1½″–#18	18	.20	.25	2′ & 4′ x 8′	1.34″	3.0″	.....	.....	.....	.....	.....
1½″–#16	16	.40	.48	2′ & 4′ x 8′	1.34″	3.0″	.38	.48	2′ & 4′ x 8′	1.34″	3.20″
1½″–#13	13	.60	.68	4′ & 6′ x 8′	1.34″	3.0″	.57	.68	3′ & 4′ x 8′	1.34″	3.20″
1½″–#10	13	.79	.89	4′ & 6′ x 8′	1.34″	3.0″	.75	.89	3′ & 4′ x 8′	1.34″	3.20″

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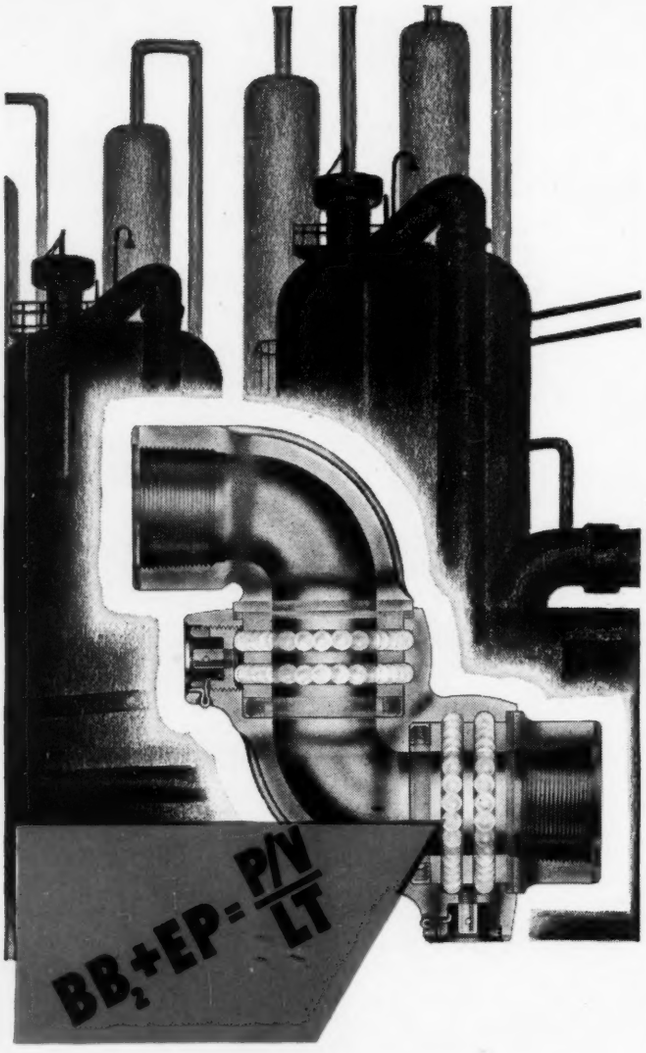

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Magnetic Compass

(*Concluded from Page* 134)

ardized as the single model used by the Army is fabricated almost entirely from thermoplastic materials, *Fig.* 1. This compass is considerably smaller and lighter than the aluminum model, being 3 inches in diameter by 5 inches in length compared with 5 inches in diameter, 8 inches in length. Its weight is 15 ounces compared with 9 pounds. The case, together with the bottom and top caps, is cellulose acetate butyrate. These same materials are also utilized for such internal working parts of the compass as the magnet holders and the spacer plates. A nonbleeding type of cellulose acetate butyrate is used for the compass card. The bowl is methyl methacrylate. Provision is made for expansion and contraction of the compass fluid by allowing sufficient air space in the bowl with a baffle plate to keep the air trapped in a chamber in the top of the bowl. The same type of compass fluid is used in both instruments. In all, 17 plastic parts go into the assembly and are produced by injection molding in multiple-cavity molds.

Assembly Methods Facilitate Production

Various methods of assembly are employed in the plastic compass. In some places, parts are cemented to each other with a common solvent. Rivets and bosses are molded into other pieces of the compass so that they project through the part to be joined. This assembly method is completed when the bosses are headed by a hot iron. A third assembly method uses conventional drilled and tapped holes for the insertion of the necessary metallic screws. Speed in production, low cost and accuracy are among the definite advantages derived from the use of plastics in this instrument.

Assembly procedures for producing both types of compasses were perfected to the point where it was possible to turn out units on a mass-production basis. Certain production tests are given to insure that the equipment meets Army specifications. The compasses are exposed to temperatures of +70C and −50C for two hours each. Any evidence of leakage or damage is cause for rejection. Compass units are subjected to a pressure of 9 inches of mercury absolute for one hour. Immediately after restoring sea level pressure they are examined for leakage. In addition to these tests, checks are made to determine the accuracy of the compass by checking card graduations, pivot friction, card balance, and the magnetic balance of the compensator magnets. Vibration tests are conducted throughout a frequency range of from 500 to 2500 cycles per minute at an amplitude of 0.020-inch. In addition to checking on the overall strength of the equipment, the vibration test shows if the compass card is readable.

In the development of these compasses a cooperative program was pursued by the Engineer Board (development agency for the Corps of Engineers), the Ordnance Department, the Pioneer Instrument Division of Bendix Aviation Corp. and the Sherrill Manufacturing Corp. Technical consultation was rendered by the Department of Terrestrial Magnetism, Carnegie Institution of Washington, D. C.

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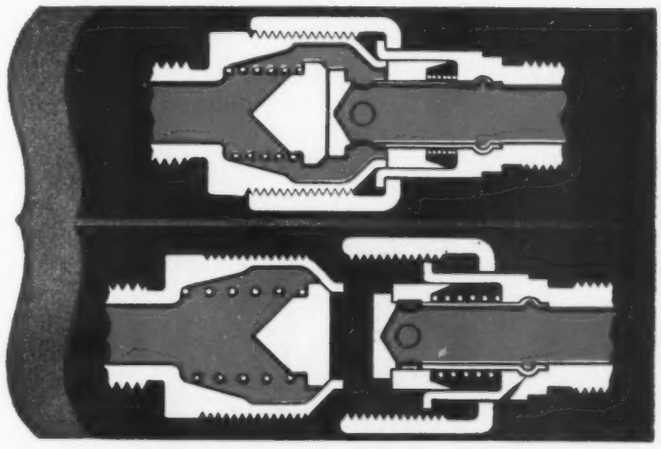

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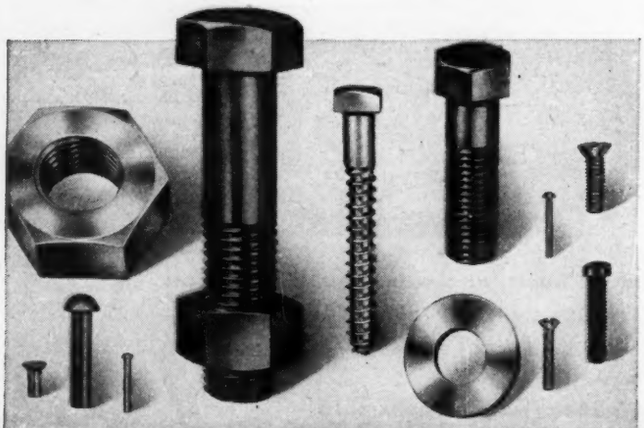

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BUSINESS AND SALES BRIEFS

ACQUISITION of Arnold Engineering Co., one of the largest manufacturers of permanent magnets, has been announced by Allegheny Ludlum Steel Corp. Ranging in size from a fraction of an ounce to 100 pounds, permanent magnets will be made in every practicable shape.

♦

With headquarters in Philadelphia, L. D. T. Berg has been named welding specialist of the Atlantic district of General Electric Co. For the past five years Mr. Berg had been sales engineer for the Electric Welding Division of the company at Schenectady.

♦

Cecil J. Bier and Art Addis have founded the Biad Powder Metallurgy Co., 6635 Kelly St., Pittsburgh 6. The company was organized to fabricate filters of all descriptions, magnetic materials, oilless bearings, electric contacts, and structural parts of iron, steel, bronze, brass, copper and aluminum.

♦

A southern sales office has been opened at Richmond, Va., by National Malleable & Steel Castings Co. William M. Blackmore, for many years associated with the development of the company's railroad products, has been placed in charge as district manager of the new office.

♦

Recently released from the Navy, Frank W. Jones had been chosen to head the Light Metal Products division of Northrop Aircraft Inc. Mr. Jones, prior to entering the Navy, had served as assistant to the president of Leighton Industries and as sales executive of Wyandotte Chemicals Co.

♦

Plans to acquire twenty-six acres on Chestnut Ave. in Hillside, N. J., have been made by the Newark Mfg. & Repair department of Westinghouse Electric Corp. The new plant will include manufacturing of switchboards, control and panel boards.

♦

Announced by General Controls Co., Glendale, Calif., is the appointment of J. M. Schlemmer as divisional sales manager of the Refrigeration Division. He has been associated with this field for over twenty years.

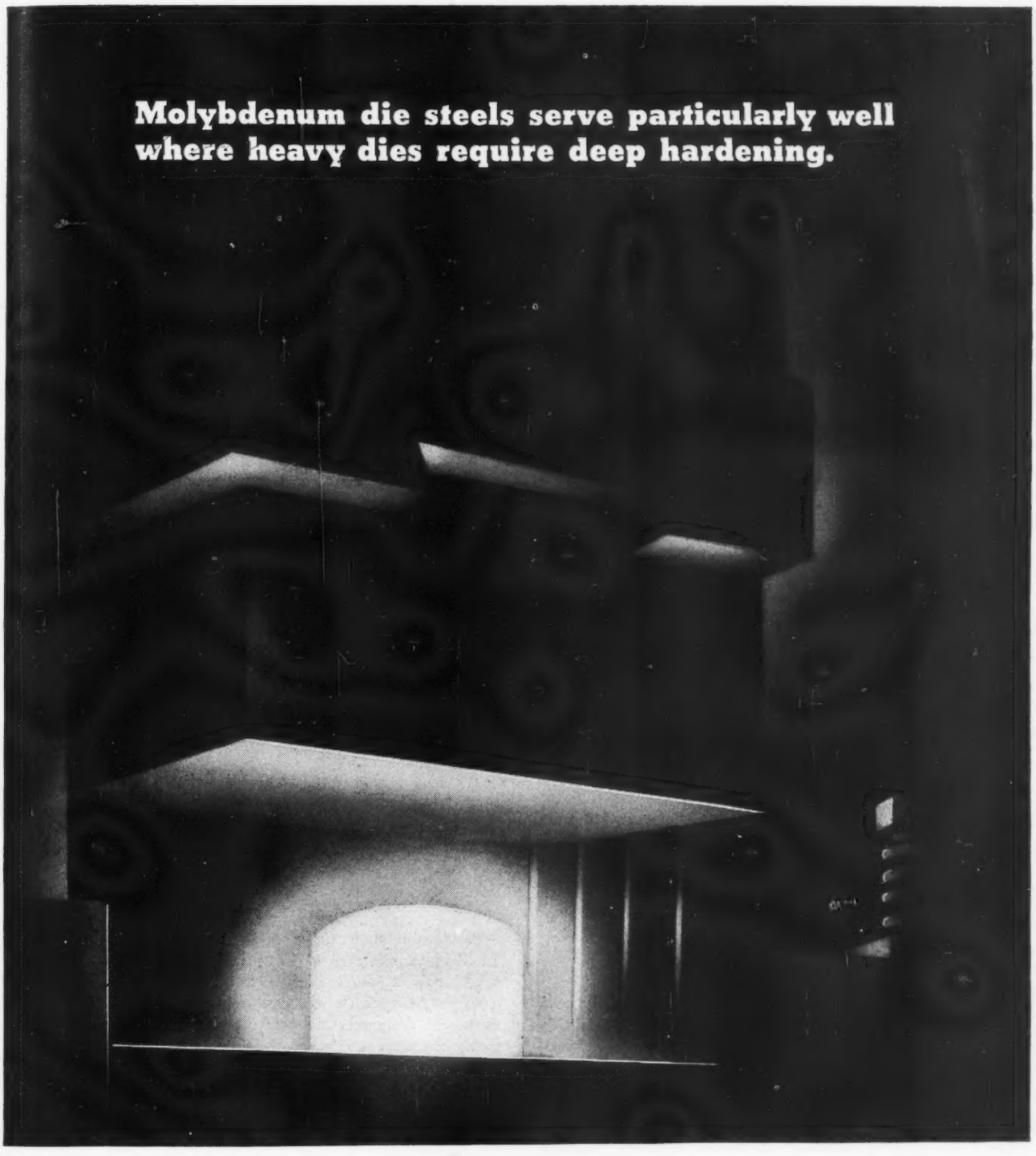
♦

Previously plant superintendent of Eastern Stainless Steel Corp. of Baltimore, F. G. Gerard has been elected vice president in charge of operations of Washington Steel Corp., Washington, Pa. This is a new company which will produce stainless steel in sheet and strip form.

♦

Serving the western Michigan area, a new welding supply house has been established by R. Dudley Layman, previously district manager and welding engineer at the Grand Rapids

Molybdenum die steels serve particularly well where heavy dies require deep hardening.



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office of The Lincoln Electric Co., Cleveland. Known as Layman Welding Supply Co., the new organization is located at 215 Oakes St., S.W., Grand Rapids, Mich. Replacing Mr. Layman at Lincoln's Grand Rapids office is I. R. Bartter, formerly district manager of the branch at Duluth, Minn.

♦

Appointment of Warren J. Kilburn as general manager of American Gear & Mfg. Co., Chicago, has been made recently. Succeeding Mr. Kilburn as sales manager is N. C. Schlegel, who had been Chicago branch manager of Boston Gear Works Inc. for the past nine years. Also announced is the appointment of Charles S. Squyres as foreign sales manager.

♦

Under the direction of James W. Calloway, a sales engineering office has been opened at 35 East Georgia St., Indianapolis 4, by the Tocco division of The Ohio Crankshaft Co. Previously Mr. Calloway had been in the Chicago Tocco office.

♦

Succeeding the late Mason Phelps is Edward M. Whiting as president of Pheoll Mfg. Co., Chicago. Prior to his election Mr. Whiting had been vice president and a director of the company.

♦

Made known recently by Electronic Laboratories Inc. is the appointment of B. G. Twyman and Associates, Chicago industrial consultants, to serve as distributors for Illinois and eastern Missouri, outside of the metropolitan districts of Chicago and St. Louis. A. E. Rodman, west coast representative, has been assigned the states of Nevada and Oregon in addition to his present territory. After a two-year absence, Herbert Jenkins has rejoined the company and will handle sales of its products.

♦

With offices at 15 Gramercy Park S., New York 3, H. B. Axtell has joined with V. A. Chern to serve as representative in the Eastern district for Progressive Welder Co., Detroit. Mr. Axtell has more than ten year's experience in resistance welding.

♦

Previously in charge of sales policy for General Electric's Small Motor Division, L. C. Spoor has been named director of sales for Eicor Inc. He will be in charge of the Eicor expanded sales program which includes the addition of a complete line of newly designed fractional horsepower a-c motors to the rotary electrical equipment of the company.

♦

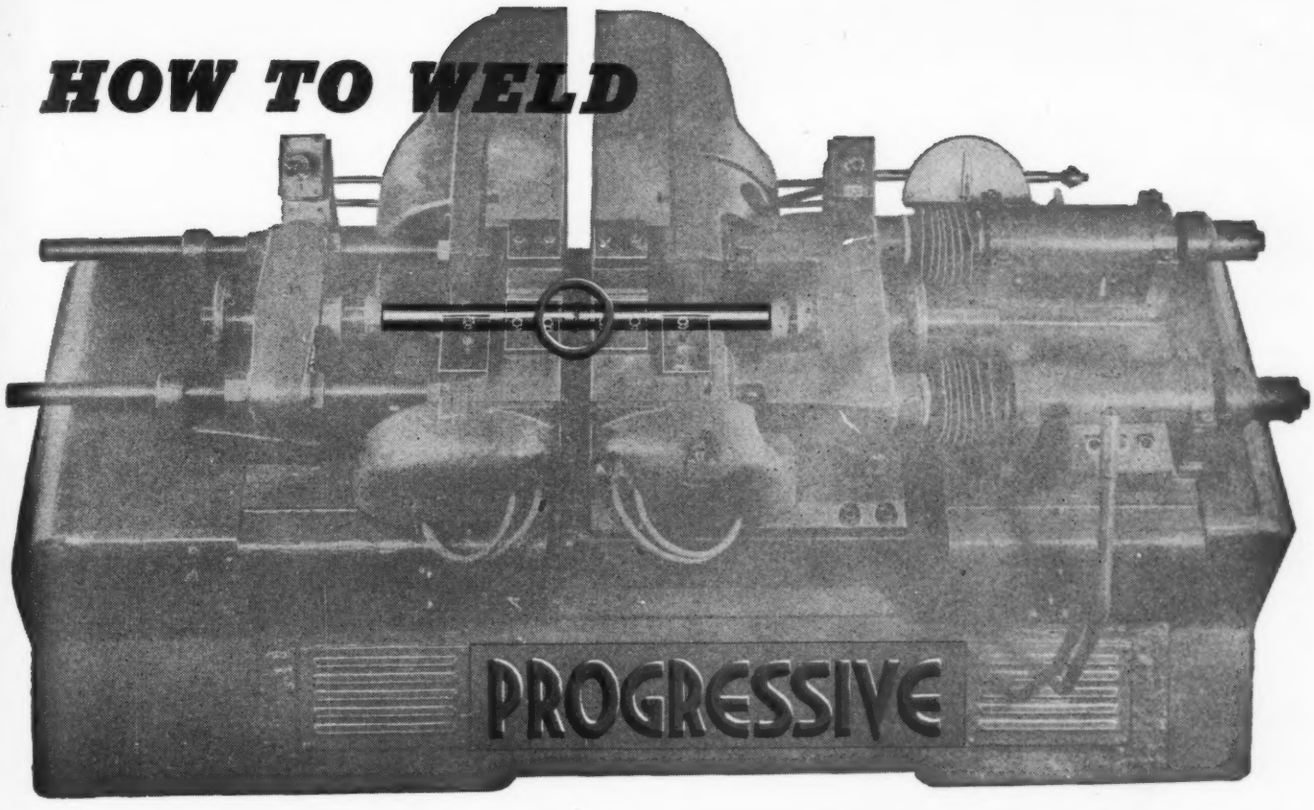
Transfer of H. A. Jules, sales representative, to the Newark, N. J., office at 457 Frelinghuysen Ave., has been announced by the R-B-M Mfg. Division of Essex Wire Corp. Formerly at the Logansport, Ind., plant, Mr. Jules now will cover the eastern seaboard from Boston to Baltimore, including southern New York state and eastern Pennsylvania.

♦

After three years active duty with the Army, K. G. Baker has returned to Wagner Electric Corp. as field engineer in the Indianapolis office.

♦

Recent promotions in its plastic materials sales staff have been made by B. F. Goodrich Chemical Co., Cleveland. These are: Advancement of George A. Fowles from manager of electric wire and cable insulating materials to sales manager for Geon thermoplastics; promotion of J. H. Field Jr. from manager of the service laboratory in Cleveland to manager of tech-



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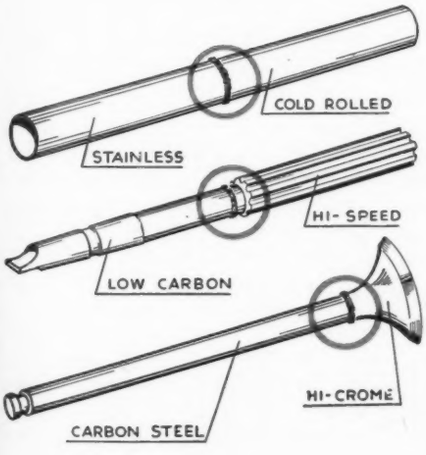

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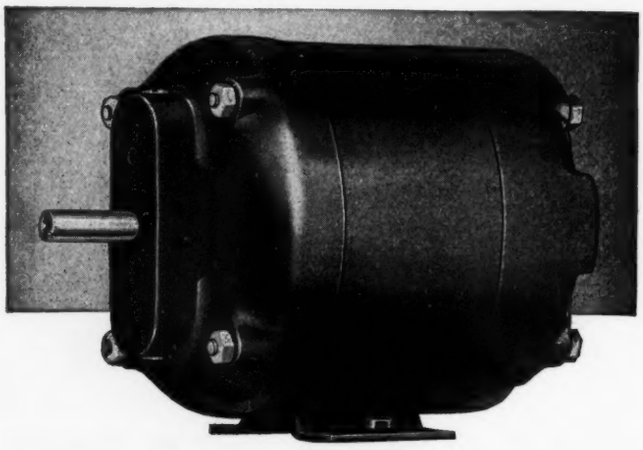

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nical service for the sales staff; advancement of M. Scott Moulton from technical service engineer for packaging materials to manager of Geon coating and film materials for the paper and textile fields; and promotion of Clyde D. Segner from technical service enginer in charge of fabric coatings to Chicago district Geon sales representative.

♦

Associated with the company for many years, Ernest Spuhler has been named general sales manager of The Fairmount Tool & Forging Co., Cleveland 6.

♦

Offices in the Neave Bldg., Cincinnati, have been opened by Walter Parks Gray, product designer and consultant. Mr. Gray had been associated with Crosley Corp. as chief designer for sixteen years. For the past year he had been chief design engineer for the Lackner Co. of Cincinnati.

♦

Ilg Electric Ventilating Co. has added the following to its sales staff: R. E. Pauling, previously with Illinois Malleable Iron Co. of Chicago, has been appointed manager of the Tulsa, Okla., office. Marion A. Elliotte, formerly in the sales engineering and product development department of Marine Products Co., has been added to the staff of the Detroit office.

♦

Following the resignation of Carl E. Payne as vice president in charge of sales and advertising, Oscar W. Hedstrom Corp. has named G. S. Swanson as sales manager.

♦

Appointment of William L. Burgoyne as special field engineer has been made by Federal Products Corp., Providence, R. I. Formerly Mr. Burgoyne had been assistant to the general manager of Wright Aeronautical Corp., Paterson, N. J., on special assignments.

♦

With headquarters at 407 South Dearborn St., R. R. Bauman has been appointed Chicago area sales representative for Ajax Flexible Coupling Co. Inc., Westfield, N. Y.

♦

Pittsburgh Equitable Meter Co. has changed its name to Rockwell Mfg. Co. The former name will be used for a subsidiary producing liquid measuring equipment in plants at Pittsburgh, Brooklyn and Hopewell, N. J. Another subsidiary, Merco Nordstrom Valve Co., has shortened its name to Nordstrom Valve Co. No change in personnel or sales policy has resulted.

♦

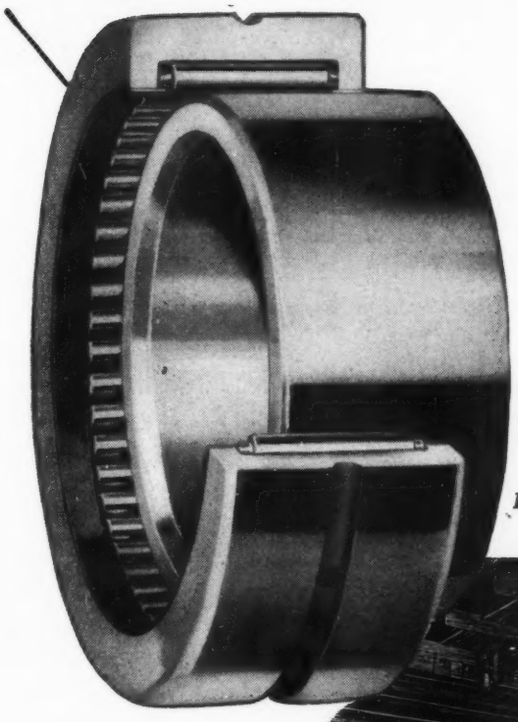
Recently released from the Army, Al G. Handschumacher has been made sales engineer of Lear Inc., with headquarters at 114 North College St., Yellow Springs, O. He will cover sections of Ohio, western Pennsylvania, Kentucky, and Indiana.

♦

Specializing in precision metal spinning, the new plant of Gyretech Corp. is now in operation at 2734 Janssen Ave., Chicago. R. H. Altman is general manager.

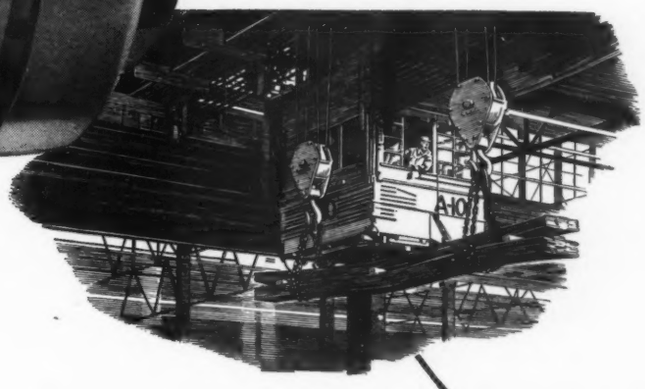
♦

Appointment of M. R. Randlett as assistant divisional director of its Milwaukee paint factory has been made by Pittsburgh Plate Glass Co. Since 1932 Mr. Randlett had been manager of trade sales at this plant. Also announced is the purchase of M. B. Suydam Co., paint and varnish manufacturer in Pitts-



PUTTING TONS ON THE SPOT

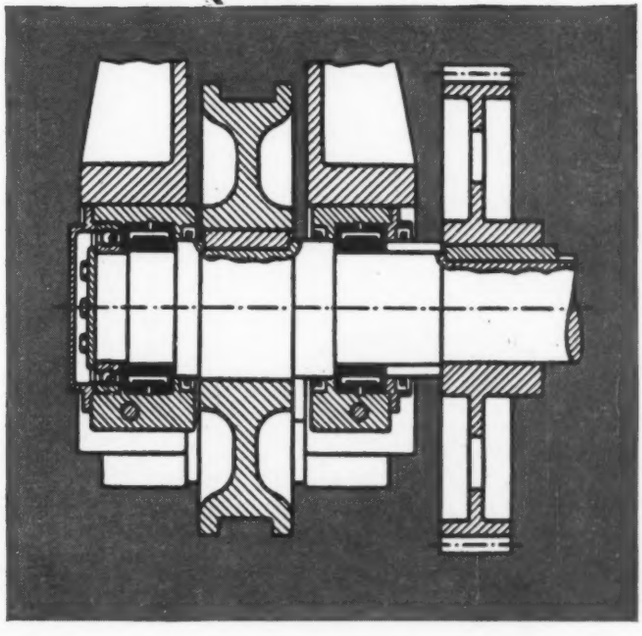
Drawing from photograph furnished by Carnegie-Illinois Steel Corporation



Whether it's a lifting job that calls for the maneuverability and operating ease of a lift truck, or a multi-ton lift that demands the strength of a giant traveling crane—*putting tons on the spot* is done by effortless, finger-tip control, when loads travel on anti-friction Torrington Bearings.

In the application illustrated, the high load capacity and compact design of the Torrington Type NCS Heavy-Duty Needle Bearings make them ideal for installation in the crane's axle housings.

Out-of-the-ordinary bearing applications are an important part of the service of Torrington's Bantam Bearings Division. Whether you need counsel on standard or large, custom-built anti-friction bearings, consult our engineering staff.



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Write at once giving full information regarding installation. Complete engineering data mailed upon request. Our Engineering Staff is at your disposal.

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burgh, and the construction of a $1,750,000 paint plant at Springdale, Pa. When completed, the new plant will manufacture a complete line of paints, varnishes, enamels and synthetic resins.

Meetings and Expositions

Jan. 11-20—

National Aircraft Show to be held at Public Auditorium, Cleveland. Additional information may be obtained from Gene P. Robers, The Weatherhead Co., 300 East 131st St., Cleveland 8.

Jan. 21-25—

American Institute of Electrical Engineers. Winter convention to be held at Engineering Societies Bldg., 33 West 39th St., New York. H. H. Henline, at the same address, is secretary.

Jan. 28-30—

American Society of Heating & Ventilating Engineers. Fifty-second annual meeting to be held at Hotel Commodore, New York. A. V. Hutchinson, 51 Madison Ave., New York 10, is secretary.

Feb. 1-2—

Society of the Plastics Industry Inc. Exhibition and meeting of the Low Pressure Industries Division of the society to be held at Edgewater Beach hotel, Chicago. W. T. Cruse, 295 Madison Ave., New York 17, is executive vice president.

Feb. 4-8—

American Society for Metals. Postponed 1945 annual convention to be held in conjunction with the National Metal congress and exposition, Public Auditorium, Cleveland. Headquarters will be at Hotel Statler. W. H. Eisenman, 7301 Euclid Ave., Cleveland 3, is secretary.

Feb. 6-8—

American Industrial Radium and X-Ray society. Annual convention to be held in conjunction with the National Metal congress and exposition, Public Auditorium, Cleveland. Headquarters will be at Hollenden hotel. Phillip D. Johnson, 25 East Washington St., Chicago, is secretary.

Feb. 25-March 1—

American Society for Testing Materials. Spring meeting and committee week to be held in Pittsburgh. Additional information may be obtained from headquarters of the society at 260 South Broad St., Philadelphia 2. Robert Painter is assistant to the secretary.

Feb. 25-March 2—

Twentieth Exposition of Chemical Industries to be held at Grand Central Palace, New York 17. Charles F. Roth, at the same address, is manager of the exposition.

April 3-5—

Society of Automotive Engineers Inc. National aeronautic meeting (Spring) to be held at Hotel New Yorker, New York. John A. C. Warner, 29 West 39th St., New York 18, is secretary and general manager.

April 10-13—

Electrochemical Society Inc. Spring congress to be held at Hotel Tutwiler, Birmingham, Ala. Colin G. Fink, 3000 Broadway, New York 27, is secretary.

April 22-27—

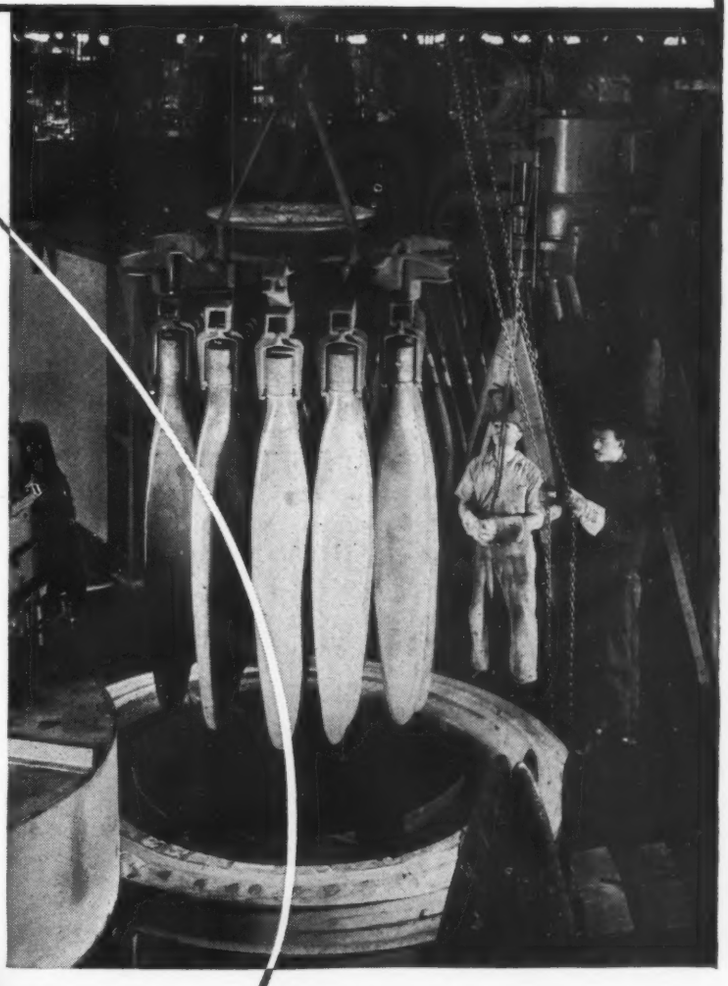
Society of the Plastics Industry Inc. First national plastics exposition to be held at Grand Central Palace, New York 17, W. T. Cruse, 295 Madison Ave., New York 17, is executive vice president.

April 27-May 19—

Products of Tomorrow Exposition to be held at Chicago Coliseum group of buildings, Chicago. Marcus W. Hinson, 1513 South Wabash Ave., Chicago, is in charge of planning and general management of the exposition.

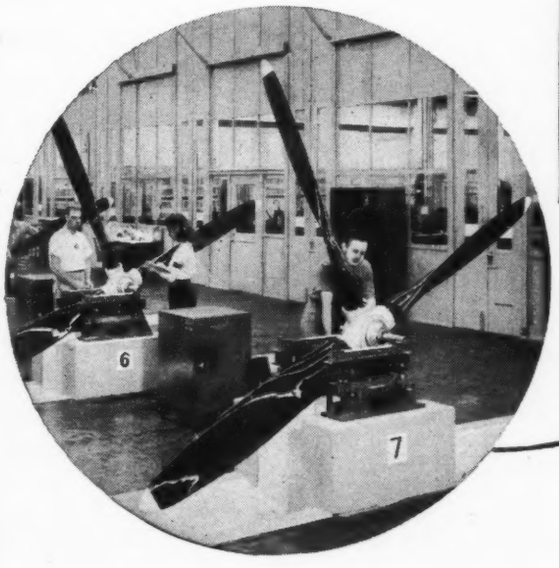
NICKEL STEELS *combine...*

EXCEPTIONAL MECHANICAL *and* FABRICATING PROPERTIES



SAE 4330 Nickel chromium molybdenum alloy steel was adopted for Curtiss propeller blades because of its high strength, toughness and good workability, coupled with a wide safe heat-treating range.

High velocity cooling is not necessary to properly harden SAE 4330 for this application. There is no warping to correct by cold-straightening operations nor danger from subsequent stresses that might cause failure in service, because the slow transformation rate of this steel permits hardening to the required degree by die-quenching; thus consequent savings in time and labor, and a uniform final product are provided.



Curtiss Propeller Division of Curtiss-Wright Corporation, one of the largest producers of constant speed propellers, fabricates blades by welding two plates of SAE 4330 into a hollow unit that permits weight saving over solid blades of light metals.

Inquiries on the use of Nickel alloy steels or other alloys containing Nickel in your products or equipment, are invited.

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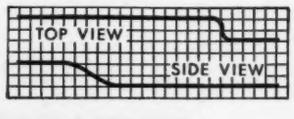
- VIBRATION CHARACTERISTICS
- TEMPERATURE CONDITIONS
- PRESENT SYSTEM
- FLEXIBLE OR RIGID HOUSING?

Make sketches of top and side views of installation. Use regular graph paper and indicate unit of measure.



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Aneroid Capsules — Chronometric Radiosondes
Fasteners and Clips of Specialized Design

NEW MACHINES—

And the Companies Behind Them

Automotive

Streamlined motorcycle, Wyse Laboratories, Dayton, O.

*Fast battery charger, The Benwood-Linze Co., St. Louis 3.

Domestic

Temperature, humidity control unit, Drayer & Hanson, Los Angeles 21.

Radio-phonograph receiver, Westinghouse Electric Corp., Baltimore 3.

Radio-phonograph, Stromberg Carlson Co., Rochester 3, N. Y.

Refrigerators, The Crosley Corp., Cincinnati 25.

*Table radio, Garod Radio Corp., Brooklyn 1.

*Tank-type vacuum cleaner, Eureka Vacuum Cleaner Co., Detroit.

*Portable clothes washer, Easy Washing Machine Corp., Syracuse, N. Y.

*Pressure cooker, National Pressure Cooker Co., Eau Claire, Wis.

Automatic ironer, Hurley Machine Div., Electric Household Utilities Corp., Chicago.

Industrial

Liquid cooler, Niagara Blower Co., New York 17.

Quadruplicate screw pump, H. K. Porter Co. Inc., Pittsburgh 22.

Two-speed electric blowers, Ace Co., Ocala, Fla.

Two-cycle, gas-engine-driven compressors, Clark Bros. Co., Olean, N. Y.

Direct-fired heater, Herbert H. Davis Co., Cicero, Ill.

Bearing cleaner, Bennel Machine Co., Inc., Brooklyn 5.

Portable steam cleaner, Siebring Mfg. Co., George, Ia.

Magnetic floor sweeper, Sjostrom Machine Co., Lawrence, Mass.

Rotary floor scraper, Carboloy Co. Inc.

Combustible gas alarm system, Davis Emergency Equipment Co. Inc., Newark 4.

Metalworking

Single-action, straight-sided press, E. W. Bliss Co., Brooklyn.

Self-contained hydraulic press, Munton Mfg. Co., Franklin Park, Ill.

Reamer and cutter grinder, Joshua Hendy Iron Works, Sunnyvale, Calif.

Pneumatic portable saw, Air Speed Tool Co., Los Angeles 44.

Hydraulic vertical gear grinder, Pratt & Whitney Div. of Niles-Bement-Pond Co., West Hartford, Conn.

Packaging

Wrapping machine for adhesive tapes, Package Machinery Co., Springfield, Mass.

Paper

*Shredder, Universal Shredder Co., Saginaw, Mich.

Testing

Tensile and compression testing machine, Steel City Testing Laboratory, Detroit 4.

Automatic electronic gage, Autotron Co., Danville, N. Y.

*Automatic piston ring inspector, Sheffield Corp., Dayton.

Textile

Preboarding machine, Proctor & Schwartz Inc., Philadelphia.

Welding

Plate edging machine, Thomas Machine Mfg. Co., Pittsburgh.

Overhead type portable spot welding units, Sciaky Bros., Chicago.

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* Illustrated on Pages 144-147.

Making Wedge Wire Screens of Stainless Steel

Fabrication of Special Screens for Industrial Purposes Requires Stainless that is Uniform and Will Stand Severe Deformation - both Hot and Cold

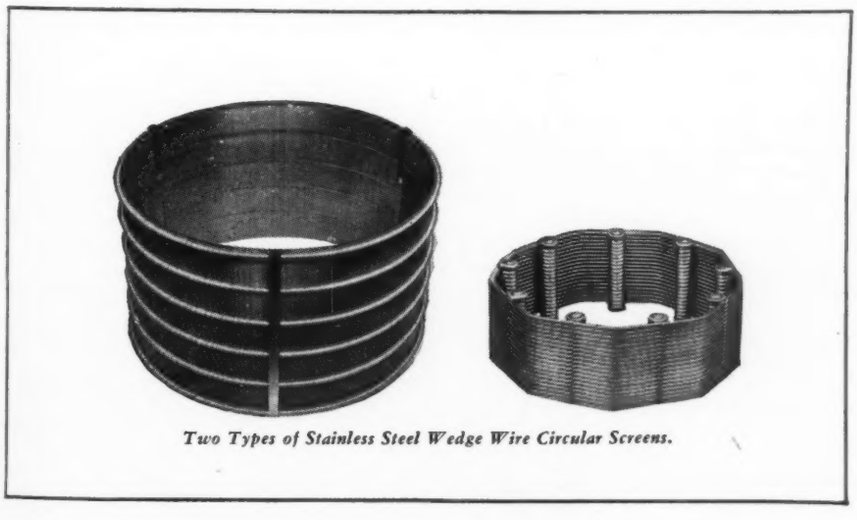
Given a stainless steel which is completely uniform—the kind that the Rustless Iron and Steel Corporation makes — and an adequate amount of sales engineering, a comparatively small company can fabricate "difficult" products of stainless steel with less trouble than is encountered with most other materials. This is the experience of Wedge Wire Corporation of Cleveland, Ohio, makers of special screens for coal washing and for foods and chemicals.

Machinery for making Wedge Wire screening was brought to this country from England only a few years ago. The unique product made with this equipment is attracting wide interest because of several advantages over ordinary wire mesh claimed for certain applications. The screen-wire itself is formed into wedge or other shapes (see next page) to produce controlled openings through which the liquid and fines being screened can pass. The fact that the surface is almost flat is one reason why Wedge Wire is less apt to clog and thus gives greater production than ordinary screen. The flared contour of the escape passage is also said to produce a desirable orifice and minimize clogging. Furthermore, of fine screening, Wedge Wire screens are more rigid than ordinary fine mesh.

Wedge Wire screens must be made to close tolerances. To achieve a high degree of control of screening the wire-to-wire openings must be held to plus or minus .002", which means holding the top widths of the wires themselves to plus or minus .001".

The assembly of the screen calls for forming loops at evenly spaced intervals in its wire members and passing tie-rods through the loops of several consecutive wires to form a screen which is rigid and in exact alignment. The loops must mate where the wires cross the tie-rods, to form tight and clog-proof joints. And the inside diameters of the loops must have a close but not binding fit on the tie-rods to form an assembly which is free from play between members but also is free from strain. All of this calls for stainless steels which will deform to exact tolerances under the dies which form the wire and loop shapes, and which will not spring back or creep appreciably after being deformed.

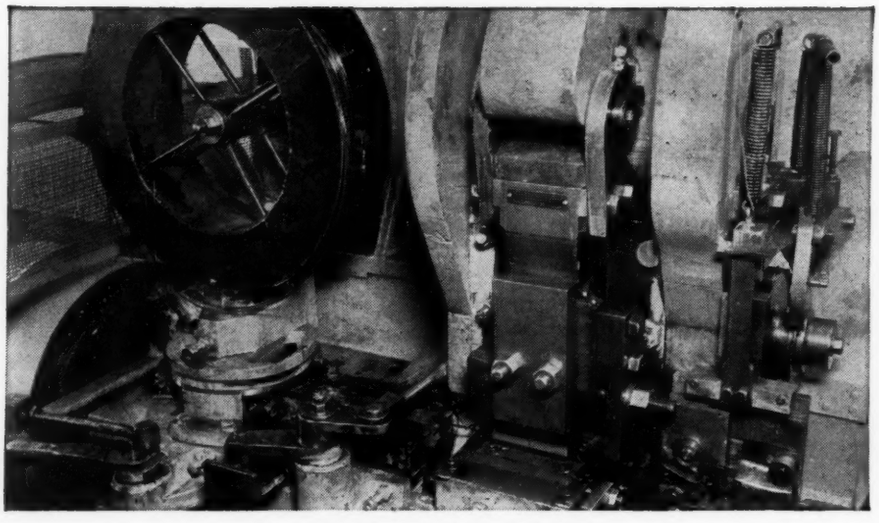
In service the screens are for dewatering, filtering, washing, drying and the separation of materials. A few of the numerous places where they may be placed are in chutes, hoppers, shakers, sluices, drag conveyors and baskets in stationary or moving frames. They are also formed into circular sections for suction filters, centrifugal and rotary screens. While retaining their true form and stiffness under such service, the screens must handle products which may be erosive, corrosive, or both. Wedge Wire screens find wide use in coal, processing plants, chemical plants, food plants, soy-bean and other oil plants, limestone plants and the like. It is because of superior structural and fatigue strength as well as resistance to both erosion and corrosion that stainless steel is used. Stainless steel not only is longer-lived in service, but with its superior mechanical properties increases the kind and amount of stress to which the screens can be subjected and thereby widens their fields of usefulness.



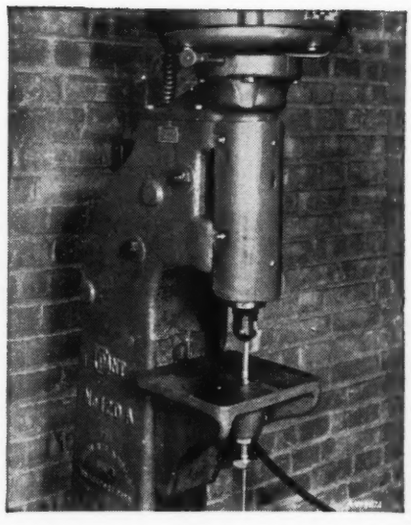
Two Types of Stainless Steel Wedge Wire Circular Screens.

Rustless 17 and 18-12-3Mo, stainless steel Types 430 and 316, are used; Type 430 is preferred for coal plants and Type 316 for chemical and food plants. The material is bought with a thin uniform electrodeposited copper coating, the copper acting as a die lubricant when forming the wires and loops. Generally the copper is not removed since it in no way affects either the performance or the durability of the screen. If it is necessary to remove the copper, this is easily done by dipping in a 10% solution of Nitric Acid. This dissolves the copper but does not affect the stainless.

Production operations include straightening the round wire which has been received in coils; cold forming the loops and cold pressing into the wedge cross section or other shaped members, cold heading one end of each tie-rod, passing the tie-rods through the loops for preliminary assembly, squeezing the wires together along the tie-rods to get the final tight and rigid assembly,



The working Area of the Forming Machine.



Cold heading on a Conventional Type Riveter.

cutting off the tie-rods to length, and hot heading the open end of the tie-rods to hold the wires in place.

Stainless steel shows definite advantages at the first or straightening operation. Straightening is done in a conventional double bending machine, with the wire being wound on special reels to fit the forming machine after the wire has been straightened. One of the purposes of straightening is to take the kinks out of the wire which resulted from possible rough handling in shipment. Once out of stainless these bends do not return as they sometimes do in other metals of which these screens can be made. That is, the proper kind and temper of stainless steel is more readily straightened, and does not spring back. This reduces fabricating costs, since bends in the wire result in stoppages at the forming machine and sometimes in broken dies.

The forming machine loops the wire, forms its cross sections to true and accurate contours, and cuts it to the length needed for the screen, all by fully automatic operations.

The first operation in this machine is forming the loop by winding the wire once around a die pin. Here the complete uniformity of Rustless stainless steel first shows its value. If all of the shipments of wire passing through this process were not alike in both size and temper, then some loops would bind too tightly on the pin so the pin could not be withdrawn to clear them, some would wind too loosely and result in oversize loops which would need special diameter tie-rods for assembly, and some might spring back after winding so that subsequent forming operations would be impossible. With Rustless stainless steel there never is any trouble.

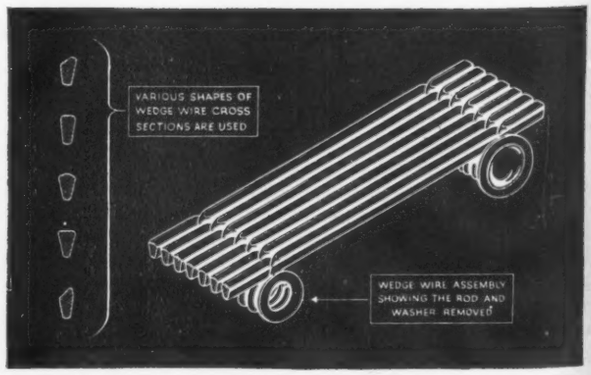
The round wire with loops in place passes to the forming dies. This forming operation is severe. It must produce flat surfaces, concave ones, or convex ones which possess two entirely different radii than those of the original wire, hold one or more dimensions to plus or minus .001", and deform the wire through about one-third of its original cross-sectional area. The loops also must receive new cross-sectional forms, and these are different from those of the straight sections of the wire. The fact that all this can be done on machines which have only ordinary press actions and which use dies made of ordinary die steels, should relieve many a metal fabricator of the idea the stainless steels are necessarily difficult to work.

Severe forming operations like these cause the metal to flow lengthwise as well as crosswise of the wire. This lengthens the distances between the already spaced and formed loops. Here the complete uniformity of Rustless stainless steel wire provides a second advantage.

Any lack of uniformity in the wire will change the distances which these loops move apart under the forming. Resetting of the machine motions can compensate for some variations in the loop spacings, but any such variations result in increased or decreased over-all lengths of the finished wires since the automatic cut-off mechanism is actuated by a counting mechanism which trips the cut-off after a preset number of strokes of the forming ram and not by anything which takes lineal measurements. The finished wires must come to correct lengths or (if not too bad) be cut to length or else be rejected. Any corrective operations whatever mean loss of machine time and of labor time as well as scrapping materials upon which expensive operations have been performed. With uniform Rustless Stainless Steels these troubles are not encountered.

Completely uniform materials also are important at the cut-off. A steel that is too hard will snap off under the cut-off tool, this tendency being enhanced by the amount of work hardening which the material can receive under the previous severe forming. A material too soft can mush or deform here. Either condition requires a corrective operation if the finished wire is to be salvaged. Completely uniform and correct material avoids this added expense.

Finished Wedge wires run automatically into a gutter of a flat,



metal-topped table. They are transferred to the table top, their loops are aligned, and just enough steel assembly guide pins to hold the wires in alignment are run through a few rows of the loops. Then the wires are transferred to the assembly department.

Primary operation of assembly is to cut stainless steel tie-rods into lengths a few inches longer than the intended widths of the finished screens. This is done in an ordinary power hack saw.

One end of each piece is cold upset to form a head against which the wire loops can bear. This upsetting is done with an ordinary air hammer or in a conventional-type rivet-spinning machine. This company never has had any trouble with upsetting operations on Rustless Stainless Steels.

The Wedge Wire loops are held to close but not extremely fine tolerances. Originally they were held to plus or minus .0015″; an over-all tolerance of .003″. But when experience proved that the inside diameters of the loops were more likely to come undersize than oversize, due to wear reducing size of the winding pin, the tie-rod dimensions were changed to plus .000″ minus .003″, thus bringing all of the tolerance to the minus side.

The fit of the loops on the tie-rods ranges from snug to light press categories, but never a force fit or a drive fit since the loops are desired to be supported but not strained and not to be given any tendency to cock or to deform during the assembly operations. The rods, then, are inserted by hand, the assembly guide pins which had been inserted at the forming machine being withdrawn.

The loose assembly is moved over so the cold-headed rod ends bear against a raised edge of the assembly table. This raised edge is to serve as one jaw of a clamp. The opposite jaw is placed against the free side of the assembly and is tightened toward the raised edge of the table. Tightening the loops together leaves an excess end of tie-rod protruding from the side. This is cut off, an adaptation of a conventional portable pneumatic shear being used for the purpose. Complete uniformity of the rod stock is important to this operation to avoid deformation of the rod ends.

Enough of the excess end is left for final hot upsetting. A stainless-steel washer is placed on this end; the end is quickly raised to red heat with an acetylene flame, and the final hot upsetting is done with a portable compressed-air hammer of conventional type. Rapid air cooling is not detrimental to Types 430 or 316 for Wedge Wire applications.

A variation of this assembly procedure is used when the screen is to be curved to be used in a centrifugal or other machine. The "top" surface of the screen can be arranged for the screened material to pass either from the outside to the inside or from the inside to the outside of the screen cylinder. In either case, it is the tie-rods and not the screen wires which must be bent. The bending is done before assembly, the rod-end usually being threaded so that nuts can hold the meeting edges of the screen to a joining member (usually a channel iron) which completes the wall of the cylinder.

A still later variation is to make the screen flat and then curve the rods in a bending brake. Mechanical techniques for this are being developed by a user of the screens but are being kept unpublicized. By such methods the finished screens can be treated as semi-finished raw materials to be formed into many special shapes for better adaptation to special purposes.

The Wedge Wire Corporation and its customers, then, are able to severely deform and re-deform stainless steels with no special or extra careful handling, no heat-treatments of any kind, no metal cleaning or other "after processes" to prevent corrosion, and almost no manufacturing rejects. They are doing no more than handle it in the offhand manner that would be accorded to "ordinary" metals. They are handling it in a trouble-free way that is made possible first by the excellent fabrication and mechanical properties of stainless steel in general, and second by the complete uniformities of Rustless Stainless Steels. And of all the factors which permit this simplicity of methods, uniformity is by far the most important.

The End.

Final hot upsetting of Rod Ends.

Rustless engineers are glad to work closely wtih those who fabricate stainless steels into industrial equipment or consumer goods. Their cooperation has been invaluable to many firms, which is natural enough since Rustless has never done anything in its entire history except produce, study, learn about stainless, how to machine, forge, heat treat, electropolish, blacken, otherwise work with stainless easily and economically. Much of the Rustless knowledge has been put into printed form. Write for helpful new chart entitled "Trade Names of Stainless Steels."

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